ALIGNMENT IN STUDENTS, TEACHING ASSISTANTS, AND INSTRUCTORS ON THE PURPOSE AND PRACTICE OF CALCULUS I LABS

by

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DEDICATION

To my mother, without whom this would not have been possible.

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ABSTRACT

While national attention has been focused on increasing the number of STEM graduates, calculus remains a roadblock into the STEM pipeline. With only half of the students succeeding in a Calculus I course, research is needed to investigate how to improve the success rate and the educational experience of students. Some research suggests that using a lab component could enhance the students' experience and aid with retaining STEM majors. The purpose of this mixed methods case study was to determine what the purpose of the lab component is according to students, teaching assistants (TAs), and instructors taking part in a Calculus I course. Furthermore, the study investigated how the views of the purpose were aligned or misaligned among the participants and if these views were aligned with the observed practice of the lab. The results indicate that the purpose of lab varied among students, TAs, and instructors especially among the different sections. Only two out of ten sections had a strong alignment in views among the three groups. When comparing the views with the practice, all three of the observed labs had evidence of misalignment. Based on interviews with the TAs, poor communication with the instructor and lack of preparation could affect the alignment of views and the alignment of views with practice. This study provides insight into how students, TAs, and instructors affect the structure of a lab classroom and discusses implications for departmental decisions regarding policy and preparation of instructors and TAs.

CHAPTER 1

INTRODUCTION

Introduction

In February of 2012, the President's Council of Advisors on Science and Technology (PCAST) published a report titled *Engage to Excel* (PCAST, 2012), which called for one million more college graduates with degrees in science, technology, engineering, and mathematics (STEM) in the next decade in order for the United States "to maintain its historical preeminence in science and technology" (p.i). In December of the same year, President Barack Obama likewise responded by calling for one million STEM graduates by 2020 (BHEF, 2013; Feder, 2012).

In a 2010 report, Business-Higher Education Forum (BHEF) argued that in order for the United States to retain a competitive edge against other countries, the number of STEM graduates must increase in order to "produce a skilled innovative workforce" (p. 2). BHEF launched the Securing America's Leadership in STEM Initiative in 2005 with the goal to double the number of STEM graduates by 2015 (BHEF, 2010). Similarly, Tapping America's Potential (TAP), a coalition of sixteen of the leading business organization in the U.S., also set a goal in 2005 for the number of STEM graduates to double by 2015 (TAP, 2008). These calls to action seek to increase U.S. competitiveness globally, but while political and economic demand for STEM degrees is high, the actual number of bachelor's degrees awarded has not drastically increased during this period. BHEF (2010) reported the number of STEM degrees has increased 5.4 percent from 2003 to 2007 while the overall number of degrees rose 13.1 percent. The trend for students completing STEM majors is discouraging to national goals. From data gathered during

1995–96 to 2001, only 53 percent of students entering a STEM major completed their degree or remained enrolled in a STEM major, and 47 percent switched to a non-STEM field or dropped from the university or college (National Center for Education Statistics, 2009). In order to reach the desired number of STEM graduates, schools must attract and hold onto their STEM majors. Retention of such majors is a vital component to meeting national goals.

Statement of Problem

While there is a high demand for graduating STEM majors, poor retention rates are part of the problem of increasing the number of graduates (Daemplfe, 2002). Seymour and Hewitt (1997) reported that 35 percent of incoming science, mathematics, and engineering (SME) majors change their major in the first year of study.

During the first year of STEM study, students enroll in introductory science, math, and engineering courses, which includes calculus (PCAST, 2012). A strong foundation and understanding of calculus is an important requirement for all STEM degrees (Young et al., 2011). Calculus, as part of undergraduate mathematics, has been a topic of conversation and reform since the 1980s (Murphy, 2006; A. Tucker, 2013). In 1987, MAA Notes series published "Calculus for a New Century: A Pump Not a Filter" and stated that calculus acts as a filter to the STEM pipeline, which in turn blocks access to STEM careers (Steen, 1987).

To investigate the state of calculus instruction, the Mathematical Association of America (MAA) conducted the Characteristics of Successful Programs in College Calculus (CSPCC) study in the fall term of 2010 that included almost 700 instructors and over 14,000 students (Bressoud, Carlson, Mesa, & Rasmussen, 2013). Of the students enrolled in Calculus I, 72 percent had STEM career goals. Half of all students earned an 'A' or 'B' for the course, which would indicate a likelihood of success in further mathematics courses, and the other half received a 'C','D', 'F', or withdrew (Bressoud, 2011a). As seen with this data, only half of Calculus I students are performing well in Calculus I courses. Thus, calculus serves as a roadblock to further STEM courses and remains a filter as the MAA calls it. If students are unable to pass the course, they are unable to progress to attain a STEM degree. Therefore, success in calculus is an important first step for most students in the pipeline from the first year of college and initial STEM aspirations to the completion of a STEM degree and finally to meeting national goals of graduating more STEM majors.

Seymour and Hewitt (1997) found that the atmosphere of science, mathematics, and engineering (SME) classrooms, which includes Calculus I, was the main concern among both students who persisted in SME and those who switched to a non-SME major. Both groups described the atmosphere as cold, the professors unapproachable, and lectures that did not invite discussion. As Bressoud (1994) found, students take on a passive role while attending lecture. Based on a review of the literature, Daempfle (2002) advocated that to increase SME student retention rates, the structure of classrooms need to be changed by trying to actively engage students.

Studies have been conducted on how to change the structure of the classroom to aid in retention. Springer, Stanne, and Donovan (1999) found that learning in small groups resulted in increased student performance and persistence in STEM. In the 1970s, Uri Treisman (1992) designed supplementary calculus workshops as way to support to minority students. By creating a sense of community, emphasizing group work, and easing the transition into the collegiate academic setting, minority students (African Americans and Hispanics in his study) outperformed other groups of students.

Currently, almost a quarter of Calculus I courses had recitation sessions led by TAs (Bressoud, 2011b), so the inclusion of recitation sessions (or labs) in calculus programs may be an important factor in student success and attrition rates. In fact, Anderson and Loftsgaarden (1987) reported that students enrolled in lecture-recitation Calculus I courses had a 3% better passing rate than students enrolled in just a lecture course. Furthermore, students generally view teaching assistants (TAs) as approachable, and positive interactions with TAs can affect a student's increased interest in the science (Kendall & Schussler, 2012; O'Neal, Wright, Cook, Perorazio & Purkiss, 2007).

Thus, a calculus lab with a TA might provide the opportunity for students to be more engaged and work actively in small groups. The lab environment could serve as a way to make up for the "cold" atmosphere of a lecture that was found to affect attrition rates of STEM students in the study by Seymour and Hewitt (1997). Using the suggestions given by Daempfle (2002), calculus labs could be a way to improve both calculus passing rates and retain STEM majors.

There is some research that examines the use of TAs in labs at the university setting. Research has examined how an introductory physics TA's beliefs aligned with their practices in lab (Chini & Al-Rawi, 2013; Lin. Henderson, Mamudi, Singh, & Yerushalmi, 2013) and the teaching concerns (Cho, Kim, Svinicki, &Decker, 2011) and self-efficacy (DeChenne & Enochs, 2010) of graduate TAs. Research has also been conducted on student perceptions of science labs and TAs (Newby & Katz, 1980; Deacon & Hajek, 2011; Kendall & Schussler, 2013). For Calculus I specifically, Fausett and

Knoll (1991) investigated which instructional format provided better student performance and how to effectively use TAs.

With the current literature, there is a gap on how TAs and students perceive Calculus I labs specifically. The typical structure of a calculus course with a lab includes an instructor leading the lecture session and the TA leading a separate session as a recitation or discussion. In theory, the instructor holds views on the lab portion of the course and influences the practice of the lab. While Volkmann, Abell, and Zgagacz (2005) investigated how a professor, a TA, and the students experience a physics course for elementary education majors, no similar research, including all three groups of people, has been conducted for calculus courses.

Purpose of Study

The purpose of the proposed study is to investigate how the lab portion of a Calculus I course is viewed by its participants (which include the instructor, the TA, and students) and how those views align with the participants and the practices in the lab.

Through a sequential mixed methods design, a case study of Calculus I labs was conducted at a large, public university in Texas. The first phase of the study included a survey given to instructors, TAs, and students to gather their views on the purpose of lab. A quantitative comparison of survey results informed how those views were aligned or misaligned. From the analysis, interesting cases were selected for an embedded qualitative case study to further explore the stated views of the participants using interviews and to see how the views aligned with classroom practices using observations. Using a mixed methods approach allowed the researcher to provide a detailed description of Calculus I labs at the chosen university.

The study answers the following research questions:

1. What is the purpose of Calculus I labs according to students, teaching assistants, and instructors?
2. How are the views of the purpose aligned or misaligned between the groups?
3. How are the views of the purpose aligned or misaligned with the classroom practices of the lab?

Significance of Study

Research is needed to see what is the perceived purpose of Calculus I labs by all persons directly involved in instruction. The views of the purpose held by instructors, TAs, and students will impact the lab environment. In order to integrate research-aligned instruction and develop an effective learning environment, it is important to know how these views are aligned and if the views are aligned with classroom practice. Because beliefs can affect decisions on classroom practices, alignment is needed for future reform to take place. Understanding how beliefs and practices intertwine can facilitate any changes needed.

Definitions

1. Calculus I – An introductory course in differential and integral calculus taught in the mathematics department. This course is a prerequisite for further mathematics courses and is a requirement for STEM majors. It is often referred to as ‘mainstream’ or ‘engineering’ calculus.
2. Lab – A separate component of a Calculus I course also referred to as a recitation session or workshop, which is led by a TA.

3. Instructor – The faculty member, usually holding a PhD in mathematics, who leads the lecture component for the Calculus I course.
4. Teaching assistant (TA) – A student, usually at a graduate level, who handles the lab component of the course. In this study, the term TA will be used for any student teaching a lab.
5. STEM – An acronym for Science, Technology, Engineering, and Mathematics, which is used to discuss fields of study at the collegiate level. Historically, the acronym has changed from Science, Mathematics, and Engineering (SME) to SME&T and SMET, and finally to STEM. Technology was not added until the 1990s when computer science became an emerging field. All four acronyms will be used based on the date of the research discussed.

CHAPTER 2

LITERATURE REVIEW

Introduction

In recent years, reports, such as *Engage to Excel* (PCAST, 2012), BHEF (2010), and TAP (2008), call for an increase in the number of STEM graduates in order for the United States to remain competitive in the global market. However, almost half of students majoring in STEM switch to a non-STEM major or withdraw from the university (NCES, 2009). This trend is alarming for the national and economic demand, but it is not a new development. Since the 1980s, reports and research have highlighted the attrition rates for STEM majors and the reasons behind this trend. Research has also focused on ways to improve retention rates and how TAs affect student learning.

Historical Focus on STEM and Calculus Reform

During the 1980s and 1990s, national and research attention was focused on increasing the number of students enrolling in science, mathematics, and engineering (SME) majors and retention rates for those majors. This focus was the result of the fact that "between 1966 and 1988 the proportion of college freshmen planning to major in science and mathematics fell by half" (Tobias, 1990). In 1986, National Science Foundation (NSF) published a report that detailed the trends of undergraduate education in SME, highlighted the need for change, and provided recommendations for institutions. The report recommended that academic institutions invest in providing high-quality education by updating curricula and resources to meet the needs of the students and for faculty members to increase participation in the education of undergraduates (NSF, 1986).

The Higher Education Research Institute (HERI) focused their attention on the number of students entering and leaving majors in mathematics and sciences (Astin & Astin, 1985; Astin & Astin, 1993). Astin and Astin (1993) collected data from 27,065 freshmen students from 388 different colleges and universities using questionnaire data over the course of four years. During those four years, the number of students majoring in SME had a relative decline of 40% with biological sciences and engineering having the greatest losses with a 50% decline and 40% decline respectively. The physical sciences only had a 20% decline, but this is due to recruitment of students leaving engineering. The study also reported that the number of students pursuing science related-careers dropped from 25% to 14%, with a 53% decline in engineering and a 51% decline in scientist or practitioner careers.

To examine exactly when during their education students decide to switch SME majors, Hilton and Lee (1988) used longitudinal and cross-sectional data from high school seniors first surveyed in 1972 and high school sophomores first surveyed in 1980. The study aimed to find critical junctures at which students "leak out of the SME pipeline" in their high school and college education, and found the greatest loss to have "occurred in the transition from high school to college" (p. 516). While students both entered and left the pipeline during the study, the losses were always greater than the gains. In college, the number of students leaving SME or the institution was greatest in the first two years. Even though the net loss was less while in college, Hilton and Lee

(1988) point out that this is due to persistence rates, not additional students entering SME.

While attention was focused on undergraduate SME education, mathematics education researchers began to turn their attention to calculus reform. In the early 1980s, there were concerned about freshmen students lacking algebra skills and the content of calculus being "watered down" as more students from computer science, biology, business, and economics began to take calculus (Tucker, 2013). A conference titled *Towards a Lean and Lively Calculus* in 1987 drew attention to the need for new calculus curriculum that would trim down the content while emphasizing applications and technology to better serve these new students (Moore and Smith, 1987; Steen, 1987; Tucker, 2013). This marked the beginning of the "Calculus Reform" movement where researchers would focus on the development of curriculum and calculus instruction and learning.

In the fall of 1987, the Mathematical Association of America (MAA) conducted a survey to gather information about the state of calculus at the time at four-year colleges and universities. Anderson and Loftsgaarden (1987) summarized the results of a survey by stating that approximately 300,000 students were enrolled in mainstream Calculus I and almost 260,000 in non-mainstream Calculus I. Mainstream calculus, also known as engineering calculus, is a freshman or sophomore course designed to be a prerequisite for upper-division mathematics courses. Non-mainstream calculus, mostly business calculus, is not designed to allow access to further mathematics courses. Of the students enrolled in mainstream calculus, less than half completed the course with a "D" or higher.

More recently in 2010, the MAA conducted a large scale study of mainstream calculus instruction titled *Characteristic of Successful Programs in College Calculus* (CSPCC) with the goal to gather data on the students taking Calculus I and to identify what factors of calculus programs and instruction improve student success (Bressoud, Carlson, Mesa, & Rasmussen, 2013). The study included surveys of 663 instructors and over 14,000 students from 213 colleges and universities. While 94% percent of the students expected to earn a grade of 'B' or higher, only 50% earned an 'A' or a 'B' for the course, which would indicate success in future mathematics courses (Bressoud, 2011a). Of the remaining students, 23% earned a 'C' and 27% earned a 'D', 'F', or withdrew from the course. While these results are better than the 1987 survey, the post survey results showed a decrease in confidence in mathematical abilities, the enjoyment of mathematics, and the desire to continue mathematics (Bressoud, Carlson, Mesa, & Rasmussen, 2013).

Reasons for Attrition in Mathematics and Sciences

Research continued into the 1990s with a focus on the state of undergraduate education in SME and attrition rates with Technology as a newly added field. In 1996, both the National Research Council (NRC) and NSF published reports stressing that science, mathematics, engineering, and technology (SME&T) undergraduate programs must not act as filters and work to "actively engage all learners" (Kyle, 1997, p.547). Through these publications, the "target of reform is thus projected beyond the classroom to the department, the institution, and to all other articulating parts of the educational system" (Seymour, 2002, p. 84).

To fix the filter issue, a number of studies were published to inform about the state of affairs. Tobias (1990) used postgraduates to audit an introductory course in calculus-based physics or chemistry. The sample included seven students who graduated in non-science fields such as history and literature. These students were selected based on high achievement in their respective fields who were considered to have the necessary background (four years of high school science and mathematics and one semester of college calculus) to take the audited science courses. The students were required to attend classes, complete homework assignments, take exams, and were asked to write about their experiences. From the results of the study, the students reported that the lectures were dull and unengaging, and there a lack of discussion, as well as a lack of community. Tobias' (1990) study challenged the notion that students were unable to comprehend the course material and as a result, dropped out of the sciences and instead, suggested that at least part of the problem had to do with instruction and classroom atmosphere. Overall this implies that even when students are intellectually capable of completing STEM coursework, they do not find it appealing to do so.

Several studies directly looked at the reasons students leave SME majors. Strenta, Elliot, Adair, Matier, and Scott (1994) investigated why students left natural sciences and engineering majors at four highly selective institutions in 1988. The results showed that students who were initially interested in the sciences were turned off by the atmosphere and instruction in the classrooms. The courses were seen as too competitive, the professors as indifferent, and the lecture as dull.

Over the course of 3 years (1990-1993), Seymour and Hewitt (1997) conducted an ethnographic study to identify factors that contribute to attrition of SME majors through interviews and focus groups with 335 students in seven different types of 4-year colleges and universities in different regions. The sample included students who had switched to non-SME majors and were in their junior or senior year (switchers) and SME majors who were close to completing their degree (non-switchers). Seymour and Hewitt (1997) found that the two groups of students, switchers and non-switchers, did not differ by "individual attributes of performance, attitude, or behavior, to any degree sufficient to explain why one group left, and the other group stayed" (p.30). In fact, both groups shared common concerns with curriculum and instruction. The students viewed science instruction as being poor quality, the professors as unapproachable, the classroom as uninviting or cold, and noted the lack of discussion as a teaching format. After the first year of study, 35% of students switched, and this decision often began with the negative experiences in the classroom.

The findings of Tobias (1990), Strenta, Elliot, Adair, Matier, and Scott (1994), and Seymour and Hewitt (1997) challenge the notion that introductory STEM courses "weed out" the poor students. STEM fields lose capable students whose interest in the sciences decreases after taking introductory courses in their first year. These students find the instruction to be poor and the courses to be uninteresting, and switch to majors with more stimulating courses.

Increasing Retention Rates

Several studies have aimed to determine how student retention rates in STEM can be improved. Springer, Stanne, and Donovan (1999) performed a meta-analysis of research focused on the effects of small-group learning in STEM undergraduates with respect to achievement, persistence, and attitudes. From the 383 reports gathered, 39 were included in the analysis due to being based on research and had large enough samples to calculate effect size. Springer, Stanne, and Donovan (1999) found that small-group learning has a statistically significant and positive effect on students in STEM. Furthermore, students who "learn in small groups generally demonstrate greater academic achievement, express more favorable attitudes toward learning, and persist through SMET[STEM] courses or programs to a greater extent than their more traditionally taught counterparts" (p. 42).

During the 1970s at University of California, Berkley, calculus was viewed as a barrier for minority students (African Americans and Hispanics), who had low passing rates which prevented access to STEM careers (Treisman, 1992). With the goal of improving the quality of instruction in an introductory calculus course, Uri Treisman observed two ethnic groups of students to understand why one group (Chinese) performed well in mathematics courses, while the other (African American) did not. Treisman (1992) found that the African American students were motivated, academically prepared, had the support of their family, but studied alone and did not discuss homework problems with the other students. The Chinese students, on the other hand, frequently worked together by checking each other's homework solutions and prepared for exams together. The academic community that the Chinese students had built helped them to prepare for and to succeed in calculus courses. With these findings, Treisman (1992) developed a workshop course for all ethnicities that focused on building a learning community to encourage students to work together. Through group work and a "challenging, yet emotionally supportive academic environment" (p.368), the African American and Hispanic students who participated in the workshop began to outperform their white and Asian counterparts. Thus, collaboration and an encouraging learning environment can lead to increased student achievement and improve retention rates.

Starting in the 1980s, universities were working on "incorporating TA's into the teaching of the calculus in a way that makes the experience for the students more satisfactory" (T. Tucker, 1986, p. 12). In lower division science and mathematics courses, TAs can play a significant role in students' experiences (Speer, Gutmann, & Murphy, 2005; O'neal et al., 2007). As Speer, Gutman, and Murphy (2005) point out, a large portion of undergraduates' instructional time may be with TAs because the responsibilities of TAs range from teaching courses, leading recitation sessions, grading homework, to tutoring students. If faculty are not able to teach using reform methods, Seymour (2001) suggests a middle path where faculty "use recitation sessions run by teaching assistants as a way to insert more active learning, and checks on student comprehension, into an otherwise unchanged lecture and lab pedagogy" (p. 87).

Studies on TAs have revealed that students' views on TAs vary and are at times conflicting. Muzaka (2009) surveyed 51 undergraduate students in a social science department at a British university about the pros and cons of using graduate teaching assistants (GTAs) to lead small group seminars. The students were concerned with the lack of a strong content knowledge, poor communication between the GTA and the instructor, and perceived the GTAs as being nervous and having less-developed teaching skills. Despite the concerns, the students viewed the GTAs as being more engaging (than the instructors) by encouraging group discussion and providing more current research in the field. The GTAs were also seen as less intimidating, easier to approach, and enthusiastic about the subject.

A study by Kendall and Schussler (2012) reported similar results. A survey was given to undergraduates enrolled in biology courses with lab components to gather student perceptions of the instructional characteristics of professors and GTAs. The results showed that students viewed the professor as more confident, experienced, knowledgeable, distant, and boring than the GTAS. On the other hand, TAs were seen as more uncertain and nervous, yet more engaging, interactive, and able to personalize teaching more than the professor. Using the same sample of students, Kendall and Schussler (2013) reported that over the course of a semester student perceptions' of TAs improved while perceptions of professors decreased.

O'Neal, Wright, Cook, Perorazio and Purkiss (2007) investigated the role of the TA in the decision-making process of science students in regards to majoring in the sciences. A survey was administered to all students who took one of seven gateway courses required for majoring in chemistry, physics, and biology. The study found that the only statistically significant factor with respect to retention and attrition was the lab climate. If students indicated a positive learning environment in the lab, there was an increased interest in science. However, students who viewed the lab environment as stressful indicated a decrease in science interest.

While student views about TAs fluctuate, if students perceive the TA as approachable and able to provide comfortable learning environment, then a lab component might improve the "chilly classroom" issue described in Seymour and Hewitt (1997). Thus, a lab run by a TA might provide a way to remediate the issues cited by students who switched out of STEM majors.

Theoretical Framework

The classroom. Faced with high attrition rates at colleges and universities, Tinto (1993) developed a model of student departure from college based on theories from social anthropology and sociology. The longitudinal model includes academic and social interactions within an institution of higher learning serving as a context for an individual's departure. Tinto posits that the classroom is central and key to both social and academic integration because the classroom is a gateway to social and academic communities. This is particularly true in freshmen classes where active student involvement must be emphasized (p.134).

The findings by Seymour and Hewitt (1997) provide support for Tinto's model in regards to SME majors. For most students, the decision to change majors began "with poor experiences in SME classes in their first year" (p. 393). Poor teaching was the most common issue expressed by both students who stay in SME and students who switch to other majors. Students felt that the professors were unapproachable and cared more about research than teaching. The classroom environment was cold with little discussion or interaction, and the material was described as dull with little evidence of application and implication.

How People Learn framework. Smith, Douglas, and Cox (2009) state that "the classroom lies at the heart of students' academic experiences" and argue for classrooms to become supportive learning environments (p.20). To enhance the learning environment, the researchers suggest the How People Learn (HPL) framework. The HPL framework was established by the National Research Council (NCR) to summarize the research on human learning in order to provide guidelines for designing effective learning environments (Bransford, Brown, & Cocking, 2000). The framework was in part developed using Wiggins and McTighe's (1997) strategy of "working backwards" and a tetrahedral model created by James Jenkins (1978) for selecting teaching strategies (as cited in Bransford, Vye, & Bateman, 2002). The working backwards strategy begins with educators analyzing learning goals and ways to assess student progress towards those goals, and then develop teachings strategies. The Jenkins' 1978 model considers the nature of the material being learned, the goals of learning, what the learner brings to the classroom, and assessment when considering the use of different teaching strategies. Bransford, Vye, and Bateman (2002) maintain that in order to design high-quality learning environments these strategies need to be advanced to include what develops and supports competence and performance in students. Thus, the HPL framework was established in order to incorporate research and to assist in the design of learning environments.

The HPL framework includes four lenses (Learner Centered, Knowledge Centered, Assessment Centered, and Community) that overlap to provide a way to analyze the quality of learning environment (Figure 1). All four lenses must be present and balanced to in order to create an effective learning environment (Bransford, Vye, & Bateman, 2002).

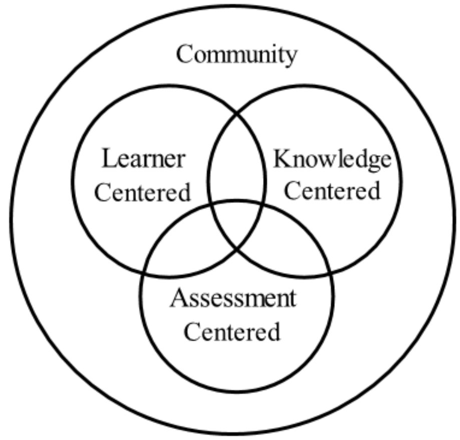

Figure 1. HPL framework. Adapted from Bransford, Vye, & Bateman (2002).

The Learner Centered lens is focused on the student and includes consideration for what the student brings to the classroom. Students have different backgrounds, cultures, and preconceptions that they bring to the classroom which teachers need to be aware of in order to connect the student to the material being taught in the classroom. A learner centered teaching approach could include diagnostic teaching as an example. Developed by Bell, O'Brien, and Shui (1980), this teaching strategy allows the teacher to identify misconceptions of the students by observing, questioning, and selecting tasks to help students to undergo cognitive conflict (as cited in Bransford, Brown, & Cocking, 2000). Another aspect of learner centered instruction is using discourse to facilitate student understanding by using both everyday discourse and discourse of the subject. In a lab environment, a learner-centered TA would aim to provide a bridge from the calculus topics to the student by considering what the students knows and is able to do. The classroom discourse would include mathematical terminology paired with everyday discourse to explain calculus concepts.

While Knowledge Centered and Learner Centered lenses overlap, Knowledge Centered addresses the learning goals of a course. The instructor should ask themselves what should be taught and why, and emphasize “connected knowledge that is organized around foundational ideas of a discipline” (Bransford, Vye, & Bateman, 2002, p. 167). The idea is to identify what the students should know and be able to do at end of a course or after graduation, and to “prepare students for future learning” (p. 168). A knowledge-centered environment would incorporate the discipline as a whole with relevant activities (e.g., Prawat, Remillard, Putnam, & Heaton (1992), as cited in Bransford, Brown, & Cocking, 2000) and focus on students making sense of the new information presented. A knowledge-centered calculus lab would allow students to think mathematically and make sense of the calculus topics without focusing entirely on computation.

The Assessment Centered lens incorporates both formative and summative assessment. Formative assessment should be used frequently in order to provide students with feedback and the opportunity to revise. If a teacher focuses on helping students to self-assess through formative assessment, student learning becomes more effective and achievement increases (e.g., Vye et al. (1997, 1998), as cited in Bransford, Brown, & Cocking, 2000). Rather than using standardized testing, summative assessment should be “indicative of performance in everyday settings” (Bransford, Vye, & Bateman, 2002, p.177). Under the “preparation for future learning” view, assessment focuses on the ability of students to learn in knowledge-rich environments which would facilitate the transfer of knowledge (p. 178). The idea behind assessment is to deemphasize facts and procedures and try to require an understanding of the subject (Bransford, Brown, & Cocking, 2000). In a calculus lab, the TA would monitor the students’ daily work while providing feedback and assessing the abilities of the students. Daily quizzes could be incorporated that aim at evaluating mathematical understanding, and the students should receive feedback from the TA and be able to submit revisions.

The fourth lens, Community Centered, stresses the importance of creating learning communities from Vygotsky's (1978) theory that learning is culturally mediated (as cited in Bransford, Vye, & Bateman, 2002). Learning communities can provide "supportive, enriched, and flexible settings where people can learn" (Bransford, Vye, & Bateman, 2002, p. 171). A learning community allows students to feel comfortable asking questions, receive information from multiple sources, and actively participate. Strong communities develop social skills, collaboration and cooperation, and allow the students to focus on learning rather than performance. The lab environment in a calculus course can provide an ideal setting for students to form a learning community and offer an atmosphere where students can communicate with each other and the TA. A TA who is community-centered would encourage students to work together, to discuss ideas, and share strategies.

To summarize, the HPL framework incorporates four lenses that intersect to organize information from research on how people learn. Thus, the framework provides a means to analyze the quality of learning environments, such as a Calculus I lab classroom.

Teacher beliefs and practices. What teachers do in a classroom is affected by the beliefs they hold (Pajares, 1992). However, research has shown that a teacher's beliefs and instructional practices may or may not be consistent (Fang, 1996; Speer, 2001). Due to the complexities of a classroom, there might be contextual factors that influence a teacher's beliefs and practices (Fang, 1996). Kilgore, Ross, and Zbikowski (1990) found that administrators and other teachers affected first-year teachers' beliefs. Similarly, Davis, Konopak, and Keadance (1993) reported that teachers' decisions about instructional practices were influenced by the students, the principal, and the cooperating teacher mentor. Thus, what occurs in the classroom is a result of the persons involved in the learning process. At a school, the district's policies, the principal, the teacher, and the students have an effect of what happens in a classroom. At the collegiate level this would be roughly analogous to deans, department chairs, the instructor, the TA, and students.

Research on TAs beliefs and practices is consistent with research cited above. Studies focused on TAs have found that the relationship between beliefs and practice varies. Lin, Henderson, Mamudi, Singh, and Yerushalmi (2013) reported conflict between the TA's self-reported research-aligned goals and the instructional practices seen in the lab. After observing three TAs' similar classroom behavior, Goertzen, Scherr, and Elby (2010) investigated the beliefs underlying the practices and established them to vary between the TAs. In comparing teachers to TAs, the TAs can be viewed as beginning teachers because for some it is their first experience managing a class. Then the TA's supervising instructor, the department of the instructor, and the students in the class can all affect the practices of the course.

Systematic agreement. Because the practice of a lab classroom could be affected by the beliefs of the supervising instructor and the students enrolled in the course, how their views align is important. In human resource development (HRD), organizational alignment refers to the degree to which the strategy, design, and culture of an organization align in order to achieve a goal (Semler, 1997). Under this theory, if an organization can create agreement within the different components about its goals, it will remove the "internal barriers to cooperation and performance that would otherwise reduce the efficiency and effectiveness of work toward those goals" (p.28). A high level of alignment will encourage productivity and create a stress-free work environment.

A university can be viewed as an organization with different programs, departments, instructors, and students as its working parts with different levels of leadership. Taylor and Newton (2013) found that when implementing institutional change at a university, alignment of goals in the stakeholders (administrators, instructors, students) was key for integrating blended learning. Senior leadership served as a principal facilitator, while lack of a concise definition of the goal was a barrier.

Narrowing down to a departmental level, the department's administrators, the faculty, and the students enrolled in the department's courses can be viewed as members of an organization. When considering a single course, such as Calculus I, alignment of views between the various members of the organization (instructors, TAs, students) will affect the classroom practices. If the three groups of members are strongly aligned in their views and goals for the classroom, then performance can increase.

Summary. The framework is summarized in Figure 2.

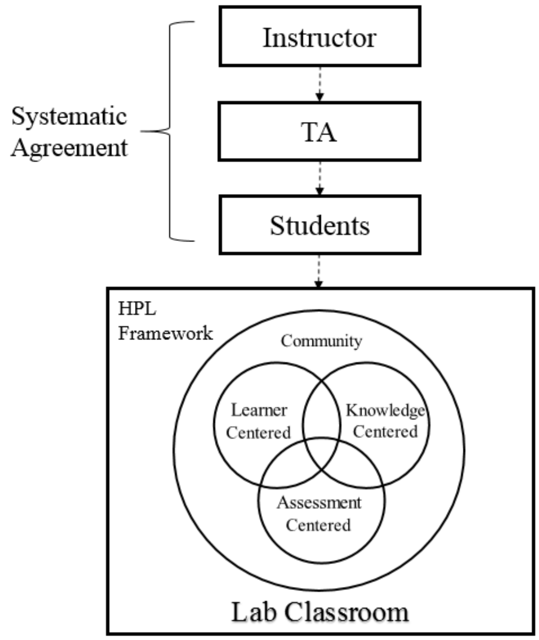

Figure 2. Summary of theoretical framework.

The lab classroom is the center of the university experience for a student, which can positively or negatively affect the student's learning. Classroom experiences can result in a student leaving the university or changing to a non-STEM major. In order to create an effective learning environment in a classroom, different components must be considered. The HPL framework incorporates community, assessment, knowledge, and the learner in the design of learning environments.

Within a lab classroom, the learning environment is affected by the instructor, the TA, and the students enrolled. The beliefs held about the purpose of the classroom need to be aligned between the different members. A high level of alignment will help to increase attainment of the purpose. If the instructor, the TA, and the students view the lab component of Calculus I in terms of the HPL framework and their views align, this allows for the creation of an effective learning environment and the achievement of the purpose of the lab component.

CHAPTER 3

METHODOLOGY

Introduction

While there is a growing need for STEM majors, the number of STEM degrees awarded is not increasing proportionately to the overall number of degrees being awarded in the United States (BHEF, 2010). Introductory mathematics and science courses fail to retain STEM majors (Daemplfe, 2002; Strenta, Elliot, Adair, Matier, & Scott, 1994, Seymour & Hewitt, 1997), and in particular, Calculus I is seen as a roadblock in the STEM pipeline (Steen, 1987). Research is needed to investigate Calculus I components in order to better understand the issues. This study investigated the lab component led by a TA in order to answer the following research questions:

1. What is the purpose of Calculus I labs according to students, teaching assistants, and instructors?
2. How are the views aligned or misaligned between the groups?
3. How are the views aligned or misaligned with the practices of the lab?

To examine how Calculus I labs are viewed, a case study approach was utilized by focusing on a single university in central Texas. This design was chosen as the university is “a real-life, contemporary bounded system” (Creswell, 2013, p.97). The students, TAs, and instructors were surveyed during the fall semester of 2014 to elicit their beliefs about the purpose of the lab portion of a Calculus I course. The numerical survey results were analyzed by calculating distances between the students averaged together, the TA, and the instructor for each section. After the initial survey and analysis, three cases were selected for classroom observation as an embedded case study, and the observations were paired with the interviews with the TAs to compare with the survey results. This allowed the researcher to see how the views of the participants aligned with the practices of the lab. By combining all of the data gathered, an overall analysis provided an overview of Calculus I labs at a single university.

Pilot Study

To prepare for this research, a pilot study was conducted in the spring of 2014. Using a single Calculus I course as a case study, the instructor, the TA, and three students were interviewed to investigate what is the perceived purpose of the lab component, to see how their views align, and to aid in the development of future surveys. The interviews were semi-structured, and the interview protocol can be found in Appendix A. To assist with observations of the lab and to describe the state of labs, an observation protocol was developed and tested among all sections of Calculus I during the spring semester. Appendix B contains the developed observation protocol. Observations were then conducted using the protocol on the selected case to see how the participants' views aligned with the practices in the lab.

Qualitative analysis of the interviews found four themes: assessment, recitation, comfortable learning environment, and communication. The lab serves as a time for assessment through quizzes and a way for the students to prepare for exams. Recitation is also a significant component of the lab with more time and more exposure to different calculus problems. Because the lab is led by a TA, who is also a student, the students are able to communicate more comfortably with the TA. This creates a comfortable learning environment in which the students are able to ask questions and work together. The views held by the instructor, the TA, and the students were aligned in two of the four themes;

recitation and communication. All of the participants viewed working problems (recitation) as part of the purpose or structure of lab, and the TA was viewed as someone with who the students could easily communicate. The other two themes, assessment and comfortable learning environment, had some misalignment. The instructor and the TA perceived the daily quizzes as formative assessment and as a way for students to self-assess their learning. However, the students viewed the quizzes as part of the daily routine and a way to enforce attendance. While all of the participants viewed the lab as a comfortable learning environment where students can ask questions, the instructor viewed the lab as a time for group work, but this view was not expressed by the TA or the students in the interviews.

The observation protocol was developed to assist the researcher in organizing and collecting data from lab classroom observations (Appendix B). In order to construct an observation protocol, each lab section offered in the spring semester was observed by the researcher. The classrooms were observed a month into the semester to allow time for the TA and students to establish classroom norms in order to observe a "typical" lab. The researcher took open field notes in order to document as many different aspects of the calculus lab as possible. The field notes were then analyzed qualitatively and three themes emerged: content, interaction, and participation. Content aims to observe which topics were covered and who selected the material to be presented. Interaction describes how the students and the TA interacted with each other, and participation refers to the level of engagement of the students in the classroom. From these themes, the observation protocol was created to facilitate future observations and allow the researcher to count instances of occurrences.

The observation protocol was then piloted by observing each TA's lab again near the end of the semester. Through five rounds of use, the protocol was able to serve as a useful tool to aide in data collection. From the second round of observations, the researcher found the labs to be TA-centered, with the TA selecting and working out the problems on the board. If given an opportunity to work on a problem on their own, the students worked independently with little evidence of group work or collaboration. Within the multiple sections of Calculus I, there was a large variation in the amount of instances of students asking questions and interacting one-on-one with the TAs.

The observations of the case study (one instructor, one TA, and three students) were then compared with the interview results, which revealed differences between the stated purpose of lab and the observed routine of the lab. Even though all of the interviewed students mentioned the comfortable atmosphere and the ability to ask questions, almost no students actually utilized the opportunity. During the observed lab, only one student asked a question. The TA frequently gave the students the opportunity to work on a problem before working it out on the board. When prompted to work on the problem, the students worked silently and independently, which is contrary to the instructor's view that the lab should utilize group work.

Using the results of the pilot study, the HPL framework was adopted to assist in categorizing the views held by the instructors, TAs, and students, and to provide a lens for analyzing the data in the larger study. The interviews assisted with the construction of the survey in the present study because the themes found in the pilot study corresponded with the four lenses of the HPL framework. Through the observations, an observation protocol was developed which contains features that were able to reflect the HPL lenses.

Because there was both alignment and misalignment of views between the participants and with the observed practice, the pilot study provided evidence that a larger study was needed. Thus, the pilot study helped to create instruments which work within the HPL framework and to inform the current study.

Design

The goal of the study is to better understand the lab portion of a Calculus I course in order to improve the learning environment for students and increase retention rates of STEM majors. Under the interpretive framework of pragmatism, knowledge is acquired from "the combination of action and reflection" (Biesta, 2010, p.112), and the outcome of the research focuses on solutions to a problem (Creswell, 2009). This paradigm emphasizes the research problem and allows the researcher to use any method available to understand the problem at hand (Patton, 2002). A mixed methods design utilizes the pragmatic worldview and works under the assumption that "collecting diverse types of data best provides an understanding of a research problem" (Creswell, 2009, p.18).

The study utilized a mixed methods design by incorporating qualitative and quantitative methods for data collection and analysis. The data was gathered using a sequential explanatory strategy which starts with the "collection and analysis of quantitative data in a first phase of research followed by the collection and analysis of qualitative data in a second phase that builds on the results of the initial quantitative results" (Creswell, 2009, p. 211). Figure 3 shows the steps in this strategy.

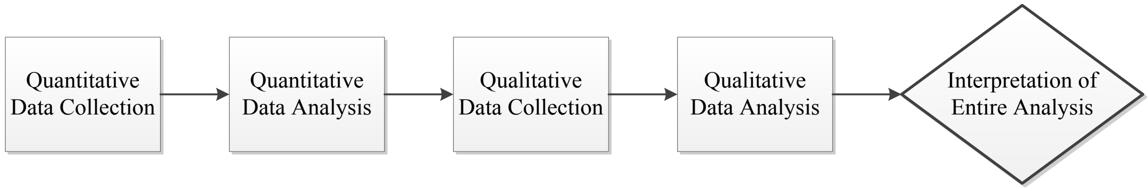

Figure 3. Sequential explanatory design. Adapted from Creswell (2009).

A single university with a Calculus I lab component was selected for the study which represents an entity with boundaries. Given that the university is bounded, a case study methodology is appropriate for the given study (Creswell, 2013; Merriam, 2009). Because the focus of the research is to investigate the case (a particular university's calculus labs), the case study becomes an intrinsic case study where the researcher is interested in the case itself (Merriam, 2009; Stake, 1995). Creswell (2013) describes case study research as a "detailed, in-depth data collection involving multiple sources of information" (p.97). The researcher collected data from surveys, observations, and interviews in order to validate the findings and to provide a more detailed description of the case.

All of the Calculus I sections offered during the semester served as the case under investigation with specific sections being selected as sub-cases for an embedded case study. An embedded case study has subunits that are used in analysis, which can combine both quantitative and qualitative methods (Scholz & Tietje, 2002; Yin, 2009). The surveys were analyzed quantitatively and then compared to the observations and interviews qualitatively. Selection of the embedded case studies was done through purposeful sampling based on the initial survey results. Purposeful sampling allows the researcher to pick "information-rich" cases that will provide details on the phenomena being investigated (Patton, 2002, p.230). To incorporate multiple perspectives, a maximum variation sampling was utilized by selecting cases that reflect differences (Creswell, 2013). For a summary of the design of the study, see Figure 4.

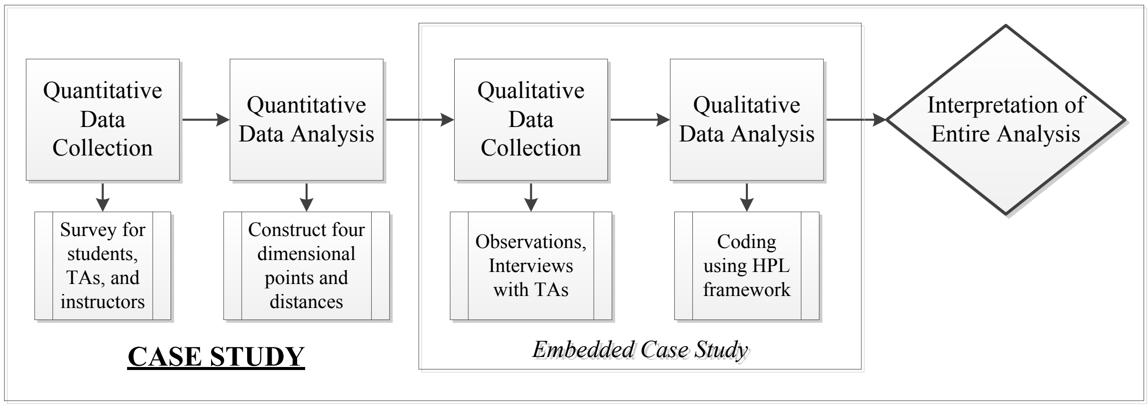

Figure 4. Study design summary.

Setting

Data was gathered from a large, public four-year university in central Texas. At this university, Calculus I is an introductory course in differential and integral calculus. The course has a lecture component lead by a faculty member and a lab component directed by a TA with the same group of students attending the lecture and the lab. The faculty members range from lecturers to professors who typically teach the course. The TAs can be undergraduate, masters, or doctoral students holding different titles. Doctoral Teaching Assistant (DTAs) and Graduate Teaching Assistants (GTAs) have 18 hours of graduate mathematics credits or a master's degree and are able to teach their own courses. Doctoral Instruction Assistants (DIAs) and Graduate Instructional Assistants (GIAs) have not met the credit hours requirement and may not teach their own courses. Undergraduate Instructional Assistant (UIAs) are undergraduate students who often major in STEM fields and are selected based on their background in tutoring.

Participants

In the fall semester of 2014, there were a total of 12 sections of Calculus I offered. All 12 served as the sample with enrollment in the course ranging from 11 to 47 students per class for a total of 403 students. There were 11 instructors and 8 TAs distributed among the sections. 2 of the 11 instructors declined to participate in the study making the sample size 9 for the instructors. Of the 9 instructors, 5 have the title of professor and 4 are lecturers. All 8 of the TAs agreed to participate in the study with the sample including 3 UIAs, 3 DIAs, and 2 DTAs. From the 403 students, 302 students who correctly completed the survey and signed the consent form were included in the study.

Instruments

Surveys. To gather views on the purpose of the lab component and to check for alignment between the participants, a survey was given to all students, TAs, and instructors who agreed to participate in the study. The participants were instructed to use a constant sum scale in order to answer the prompt "The purpose of lab is…". The survey contained 16 items with 4 items for each of the four lenses of the HPL framework (Learner Centered, Knowledge Centered, Assessment Centered, and Community). The items were constructed using the HPL framework and the pilot data gathered in the spring semester of 2014. The participants were asked to distribute the 16 points among the 16 items to indicate what they thought to be the purpose of Calculus I labs. The more points an item received, the stronger the participant felt about that item in terms of the purpose. Figure 5 provides the top portion of the student survey containing the instructions and the first four items which correspond to the Learner Centered lens.

The Purpose of Calculus I Labs – Student Survey

Read the following 16 statements and consider which ones represent the purpose of Calculus I lab in your opinion. You are given a total of 16 points to distribute among 16 statements however you would like (assign a value between 0 and 16 to all items). You must use all 16 points. Please make sure the points add up to 16 by including a total count at the end.

The purpose of lab is….	Points
1. to provide an opportunity for me to contribute personally to the lab classroom.	____
2. for the TA to be aware of and encourage my individuality and culture.	____
3. for me to have the material explained in a way that I understand.	____
4. for me to use my previous knowledge to apply it to new calculus topics.	____

Figure 5. Portion of students' survey.

The items for the students are worded slightly different from the items for TAs and the instructors to reflect the perspective of the participant. For example, the first item on the students' survey is "to provide an opportunity for me to contribute personally to the lab classroom" while the first item is worded "to provide an opportunity for students to contribute personally to the lab classroom" for TAs and instructors. The complete survey given to the students can be found in Appendix C, to the TAs in Appendix D, and to the instructors in Appendix E.

Prior to distribution for the study, the survey was piloted in a single Calculus II lab using the students and the TA. Based on the completed surveys and students' feedback, minor changes were made to the directions to make them clearer. No changes were made to the any of the survey items. Because the students and the TA distributed their points in varying ways, the survey was deemed to be appropriate for gathering the views regarding the purpose of the lab.

Observation protocol. To help with the data collection of observations in the lab classroom, an observation protocol was utilized. The observation protocol was constructed during the pilot study (see Appendix B) and was revised during the summer of 2014 to be more aligned with the HPL framework and an existing observation protocol.

The pilot protocol used three themes to describe the events and interactions seen during the calculus labs. The theme ‘content’, which describes what topics were covered or material presented, included problems selected either by the TA, the students, or instructor, a review of lecture or pre-calculus material (algebra or trigonometry), or supplementary notes to the lecture. ‘Interaction’, as a theme, included one-on-one time with the TA, students asking the TA questions, and the TA appropriately responding to the students’ questions. The third theme, ‘participation’, referred to the level of engagement of the students in the classroom. Attendance was also factored into this theme because this could indicate the importance a student placed on the lab component. See Figure 6 for a portion of the pilot observation protocol.

Name of TA:_____________ Date and Time:____________ No Students Beginning of Class:____

Events	Type	Notes
0-10min	Problem Selection o Student o TA o Lecturer Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		

Figure 6. Portion of pilot observation protocol.

The protocol was split into 10 minute intervals to facilitate note taking and reflection. To ease the documentation of events, the column “Type” was used to mark which event occurred and to count the number of instances the event occurred by making tally marks next to the marked event. If a student arrived late or left early, in the “Type” column, there is room for tally marks to count the number of students arriving late or leaving early. In order to measure how involved and occupied the students were during the lab, a section is included on the observation protocol for notes on student engagement titled “Eng Check”. The engagement check appears at the end of each ten minute interval. Aside from incorporating the three themes found, the observation protocol included a section for taking notes in order to provide explanations for marking instances, giving more details, and for any additional observations.

While the pilot observation protocol was able to include the parts of Knowledge- and Learner-Centered lenses of the HPL framework, there were no components that included some of the aspects of assessment and community. The observation protocol needed to be revised to better capture elements of learning environments that were aligned to HPL, so established observation instruments were considered.

In 1999, four research universities began a NSF supported research center (VaNTH) to focus on improving postsecondary education in bioengineering (Harris & Cox, 2003). Through this collaboration, an observation instrument, VaNTH Observation System (VOS), was developed using the HPL framework in order to assess the quality of classrooms. VOS collects data using a handheld personal data assistant (PDA) and cycles between four components. The four components include student-teacher interactions, student engagement, classroom events, and rating the quality of instruction. The Classroom Interaction Observation (CIO) captures student-teacher interactions with a string of codes to indicate who, to whom, said/did what, how, and what media was used. The user of VOS categorizes the interaction based on which lens of the HPL framework is present. The Student Engagement Observation (SEO) allows the user to enter counts of students participating in various categories of "both desirable and undesirable classroom activities", such as discussion, collaboration, social interaction, and sleeping (Harris & Cox, 2003, p. 331). What happened during the lesson is recorded by the observer using a contextual framework in Narrative Notes (NN), and the observer is able to rate the effectiveness of the teacher using Global Ratings (GB), which features Likert scale items reflecting research-based teaching practices.

While Harris and Cox (2003) reported an inter-rater reliability using VOS to be between 85 to 91 percent, Cox (2005) found that content experts only achieved a 25% agreement on HPL combination ratings. The CIO only allows for one of the four lenses of the HPL framework to be selected for each observed student-teacher interaction. Because the lenses can and do overlap with each other when observed in a classroom setting, observed interactions should be able to be categorized with multiple lenses. Thus, for the proposed study, VOS elements, not the full instrument, were considered during the revision of the observation protocol.

The revised observation protocol, Calculus Lab Observation Protocol (CLOP), retains some aspects of the original version (see Appendix F for the full revised protocol, Figure 7 for a segment of the protocol). For organization, CLOP is portioned into 10 minute intervals. Each segment contains room to tally instances and a space for note taking. At the beginning of the first page, there is space for descriptive aspects of the lab section being observed. On the last page, additional room is given for note taking, post-observation reflection, and stating assessment(s).

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

Name of TA: _________ Date/Time: ________ Enrollment: ___ No. Students: ____

Time	Tally		Notes
0-10 min Late ☐ Early ☐	Problem Selection ☐ Instructor ☐ TA ☐ Student(s) Content ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary Group Work ☐ None ☐ Unstructured ☐ Structured	Problem Presentation ☐ TA ☐ Student(s) Interaction ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	
Engagement Check: Structure:			

Figure 7. Portion of Calculus Lab Observation Protocol (CLOP).

As seen in Figure 7, ‘Problem Selection’, ‘Content’, and ‘Engagement Check’ were preserved from the pilot protocol (Figure 6) with ‘Material Covered’ retitled as ‘Content’. ‘The section ‘Interaction’ was also retained, but edited to reflect more HPL-aligned classroom practices. The option for a student asking a question and receiving a response from another student was added. Also, instances of the TA asking for or encouraging student questions can be recorded. Both of these items were present in Harris and Cox’s (2003) VOS instrument through the codes of the CIO and the ratings of the GR.

Two tally sections, ‘Problem Presentation’ and ‘Group Work’ are completely new to the protocol. In a calculus lab that is learner-centered, the students would be involved in the presentation of problems and engage in group work. ‘Problem Presentation’ allows the observer to tally instances when either the TA or a student presented their solution to a problem in front of the entire class. Both of these interactions were included in the NN section of the VOS (Harris & Cox, 2003). The section ‘Group Work’ includes options for various types of group work. Structured group work describes the case where students are assigned into pre-determined groups, whereas unstructured refers to the majority of students grouping themselves by different means in other to collaborate. If little evidence of students working together is observed, then the option ‘None’ would be marked. Group work as collaboration appeared on the CIO, SEO, and GR portions of the VOS (Harris & Cox, 2003). To reflect the NN section of VOS, a section titled ‘Structure’ was added to give the observer a space to provide an overall summary of the activities seen during that time segment.

Interviews. To facilitate the classification of observed classroom practices within the HPL framework, interviews were conducted with each of the TAs after each of the three observations. An interview protocol was developed immediately after each observation. The protocols contained a set of questions for all TAs and a set of different questions for each TA based on their separate observed labs. The tailored interview questions aimed to understand the instructional decisions made by the TA during the observed class. Appendices G, H, and I contain the interview protocols for the first, second, and third observation, respectively. The interview were recorded with a digital audio recorder and then transcribed using an online transcription service (Rev).

Data Collection

To gather views regarding the purpose of the lab, the survey was given to students, TAs, and instructors after the third week of the fall semester, and the surveys were returned within two weeks. This time frame was utilized to allow the participants to experience the lab environment, to develop classroom norms, and provide some flexibility for scheduling the survey during class. The survey was given to each instructor to complete on their own and then collected by the researcher or returned to the researcher. The TA and student surveys were administered by the researcher at the beginning of the scheduled lab time. When scheduling conflicts occurred, the TA was instructed to give the survey to the students and then complete their own while the students finished. Each survey came with a description of the study and a consent form to sign.

After the surveys were collected, the responses were entered into an Excel spreadsheet and analyzed quantitatively. Any differences between instructor, TA, and student responses in each section were noted. From the results, three sections were selected for the embedded case study. The cases were selected based on their differences to include multiple perspectives. One section was selected due to alignment between the students, the TA, and the instructor. The other two sections were selected on account of the misalignment. Description of the quantitative analysis, embedded case study sections, and details on the selection of cases will be discussed in the Data Analysis section.

The three lab sections for the embedded case study were observed using the observation protocol CLOP three times during the semester. The first observation of the lab occurred during midterms, and the other two observations were spaced three weeks apart with the last observation taking place during the last week of classes. The multiple observations allowed the researcher to construct a typical day for each of the three sections and to check for consistency. After each round of observations, the TAs were interviewed using the semi-structure interview protocols. The observations and interviews were analyzed qualitatively, and then compared to the survey results. Qualitative analysis methods are detailed in the Data Analysis section.

Data Analysis

Quantitative. The survey given to the students, the TAs, and the instructors contained 16 items grouped into four categories using the HPL framework (Appendices C, D, and E): Learner Centered, Knowledge Centered, Assessment Centered, and Community Centered. For each participant, the points allotted for each lens were combined and then converted to a proportion of the total number of points available. For example, if a participant gave the points 1, 0, 2, and 1 to the first four items, respectively, then the Learner Centered lens was given 4 points total, and the proportion would be $4/16 = 0.25$. A participant that is balanced among the four lenses would have $(0.25, 0.25, 0.25, 0.25)$ as their point. As a result, each participant was given a four-dimensional point with each lens given a proportion or weight.

In order to determine the purpose of the lab according to the groups of participants, all nine instructors, all eight TAs, and all surveyed students were grouped accordingly. A single point was created to represent each of the three groups by finding the arithmetic average for each of the four lenses using the proportions constructed. The constructed point for each group reflects that group's view of the purpose.

To select participants for the embedded case study and to determine alignment of views, each section was considered by calculating the Euclidean distance between the four-dimensional points of the instructor, the TA, and the students averaged together. The distance was then calculated between the students and the instructor (S – I), the TA and the instructor (T – I), and the students and the TA (S – T). Table 1 displays this data. On account that two instructors declined to participate, two sections were not considered for the embedded cases.

Table 1
Distances between Groups for Each Section

Section	Distance	Section	Distance	Section	Distance	Section	Distance
#1		**#4**		**#7**		**#10**	
S – I	0.099	S – I	0.098	S – I	0.152	S – I	-
T – I	0.153	T – I	0.385	T – I	0.159	T – I	-
S – T	0.137	S – T	0.387	S – T	0.153	S – T	0.352
#2		**#5**		**#8**		**#11**	
S – I	0.290	S – I	0.306	S – I	0.235	S – I	-
T – I	0.451	T – I	0.395	T – I	0.319	T – I	-
S – T	0.177	S – T	0.121	S – T	0.185	S – T	0.209
#3		**#6**		**#9**		**#12**	
S – I	0.241	S – I	0.440	S – I	0.172	S – I	0.301
T – I	0.217	T – I	0.424	T – I	0.265	T – I	0.293
S – T	0.241	S – T	0.296	S – T	0.168	S – T	0.128

Note. Distances between the student and instructor and between the TA and instructor are not available for section 10 and 11 because of missing survey data for the instructor. Abbreviations: Students (S), TAs (T), Instructors (I)

To select the embedded cases, a maximum variation sampling was used in order to "increase the likelihood that the findings reflect differences or different perspective" which is an ideal scenario in qualitative research (Creswell, 2007, p. 157). The cases were chosen by comparing the calculated distances between the groups. Sections 1 and 7 were considered due to the small distances between the instructor, the TA, and the students which would indicate alignment of views. On account of a scheduling conflict, section 7 was the one selected to serve as an embedded case. Due to large S – I and T – I distances, but a small S –T distance, the instructor was considered misaligned from the students and TA in section 5. Similarly, section 4 showed the TA to be misaligned from the other groups due to large distances for T – I and S – T with a small distance for S – I. Thus, sections 5 and 4 were selected as the other two embedded cases to reflect a variety of perspectives. In Chapter 4, the selected sections will be referred to as Lab A, Lab B, and Lab C.

In order to answer the research question regarding alignment of views, each calculated distance was classified as small, medium, or large by finding the range of the distances and then partitioning the range into three equal lengths. Any distances that fell between $0.01 - 0.216$ were determined to be small, between $0.217 - 0.333$ as medium, and between $0.334 - 0.451$ as large. Once the distances were labeled, the alignment of each section was determined as shown in Table 2.

Table 2

Distances and Alignment between Groups for Each Section

Comparison	Distance	Alignment	Comparison	Distance	Alignment
Section #1			**Section #7**		
S – I	Small		S – I	Small	
T – I	Small	High	T – I	Small	High
S – T	Small		S – T	Small	
Section #2			**Section #8**		
S – I	Medium		S – I	Medium	
T – I	Large	Moderate	T – I	Medium	Moderate
S – T	Small		S – T	Small	
Section #3			**Section #9**		
S – I	Medium		S – I	Small	
T – I	Medium	Low	T – I	Medium	Moderate
S – T	Medium		S – T	Small	
Section #4			**Section #10**		
S – I	Small		S – I	-	
T – I	Large	Moderate	T – I	-	N/A
S – T	Large		S – T	Large	
Section #5			**Section #11**		
S – I	Medium		S – I	-	
T – I	Large	Moderate	T – I	-	N/A
S – T	Small		S – T	Small	
Section #6			**Section #12**		
S – I	Large		S – I	Medium	
T – I	Large	Low	T – I	Medium	Moderate
S – T	Medium		S – T	Small	

Note. Distances between the student and instructor and between the TA and instructor are not available for section 10 and 11 because of missing survey data for the instructor. As a result, alignment could not be determined for these sections. Abbreviations: Students (S), TAs (T), Instructors (I)

If all three distances (S – I, T – I, S – T) were classified as small, then the section was considered aligned between participants and was labeled with a high level of alignment. A moderate level of alignment was given if one or two of the distances were small, which would indicate that there was some alignment between groups. If none of the distances were small, then the section would be classified as having a low alignment.

Qualitative. The labs for the three sections selected for the embedded case study were observed three times during the semester using CLOP (Appendix F). After each observation, the TA was interviewed using an interview protocol (Appendices G, H, and I). Each section was analyzed separately by first coding an observation and then coding the interview that followed the observation. Both CLOP and the interviews were coded using the four lenses of the HPL framework: Learner Centered, Knowledge Centered, Assessment Centered, and Community Centered. This strategy for analysis follows from the theoretical propositions in the case study design (Yin, 2009). Creswell (2007) warns against the use of preexisting codes because they may limit the analysis. Thus, open coding was also used to allow for unexpected events that might provide surprising or interesting information (Creswell, 2007; Merriam, 2009). The TA interviews were used to ensure the accuracy of the coding process for the observations and to allow for triangulation of data.

The coding and analysis occurred for one section at a time. Using the four lenses of HPL as codes, the research first coded an observation and then the interview that followed the observation. The coded interview was compared to the coded observation to check for consistency. After all of the observations and interviews were coded, the researcher compared the three observations and three interviews to verify consistent coding among the four lenses. In addition to the HPL coding, the researcher included additional codes as needed to allow for development of unexpected themes and to provide explanation for the observed practices. While no additional themes were found, the additional codes helped the researcher to construct a detailed description of the lab.

Following the coding process, a detailed summary of the section was written in terms of the four lenses of HPL using the observations and interviews as evidence. From this summary, the researcher grouped the evidence in each lens into themes that best describe that lens for the given section. Using a particular section as an example (Lab A), the description of the Community Centered lens could be summarized by themes of Group Work and Communication. From the developed themes for each lab section, the researcher determined how the practice of a particular lab aligned with the HPL framework. This allowed for a comparison between the views expressed by the participants on the surveys and the observed practice of the lab in terms of the HPL framework.

Mixed methods. A mixed analysis included comparing the quantitative and qualitative data collected and the results (Onwuegbuzie & Combs, 2010). The survey results and the themes from the observations triangulated with TA interviews were compared for each section. Any similarities or differences in the stated views on the surveys and the observed practices were noted. For example, if the students heavily weighted the Community Centered lens, but there were few instances or no community theme emerged from the observation, then this highlights a difference between the students' views and practice. This may be a result of misalignment of views between the students, the TA, and the instructor.

When the mixed analysis was complete, the data was integrated and considered as a whole (Creswell, 2007; Onwuegbuzie & Combs, 2010). The surveys, observations, and interviews were able to provide an overall description of the case under study and were used to answer the research questions, which can be found in Chapter 4.

CHAPTER 4

RESULTS

Introduction

In this chapter, the research questions will be answered based on the survey data, observations, and interviews. The survey results for the purpose of Calculus I labs in terms of the HPL framework will be presented for all of the students, all of the TAs, and all of the instructors averaged together, and then for each section of Calculus I separately. Next, the survey results for the three embedded cases will be provided, followed by a summary of the four HPL lenses for each of the three labs observed. Lastly, all of the data will be merged to form a cohesive whole to address the research questions:

1. What is the purpose of Calculus I labs according to students, teaching assistants, and instructors?
2. How are the views of the purpose aligned or misaligned between the groups?
3. How are the views of the purpose aligned or misaligned with the classroom practices of the lab?

Purpose by Groups

A survey was given to students, instructors, and TAs to gather views on the purpose of Calculus I labs. The survey results allowed for the construction of a four-dimensional point for each of the participants representing the four lenses of the HPL framework: Learner Centered, Knowledge Centered, Assessment Centered, and Community Centered. A description of the survey and methods of analysis can be found in Chapter 3. All 302 students were averaged together to form a single four-dimensional point representing the students as a group. The same was done with the eight TAs and the nine instructors. The results are presented in Table 3, where the lenses are abbreviated as follows: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), and Community Centered (CC). Perfect balance among the four lenses would be represented as $(0.25, 0.25, 0.25, 0.25)$.

Table 3

Purpose of Lab by Averaged Groups within HPL Framework

Group	LC	KC	AC	CC
Students	0.229	0.336	0.211	0.225
Instructors	0.146	0.295	0.240	0.319
TAs	0.164	0.328	0.164	0.344

Note: Abbreviations: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC)

Overall, of the four lenses, the students put the most emphasis on the Knowledge Centered lens for the purpose of Calculus I labs with a proportion of 0.336. Nearly equal weights were given to the Learner and Community Centered lenses. The students least preferred the Assessment Centered lens, but only by a marginal amount. Out of the four lenses, the instructors gave the most weight to the Community Centered lens with a value of 0.319. The Knowledge Centered lens followed closely with a proportion of 0.295, and then slightly less than a quarter of the weight was given to the Assessment Centered lens. The instructors were least learner-centered of all of the lenses. As a whole, the TAs viewed the Knowledge Centered lens and the Community Centered lens almost equally with proportions of 0.328 and 0.344, respectively, but were slightly more community-oriented. The Learner Centered and Assessment Centered lenses were weighted equally by the TAs but were given half as much proportion of the points as the other two lenses.

To compare how each lens was weighted among the groups, Table 4 ranks students, TAs, and instructors in each of the four lenses. Students are denoted with an 'S', TAs with a 'T', and instructors with an 'I'.

Table 4
Ranked Purpose of Lab by Averaged Groups

LC	KC	AC	CC
S – 0.229	**S** – 0.336	**I** – 0.240	**T** – 0.344
T – 0.164	**T** – 0.328	**S** – 0.211	**I** – 0.319
I – 0.146	**I** – 0.295	**T** – 0.164	**S** – 0.225

Note: Abbreviations: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC), Students (S), TAs (T), Instructors (I)

For the Learner Centered lens and the Knowledge Centered lens, the rankings were similar. Students were more learner-centered and knowledge-centered than the TAs and the instructors. This was more significant for the Learner Centered lens than the Knowledge Centered with the difference in proportions being larger. The TAs were only lightly less knowledge-centered than the students, and among the three groups, the instructors were the least learner- and knowledge- centered. However, for the Assessment Centered lens, instructors were the highest ranked. Thus, instructors placed more weight on assessment than students or TAs. There was more of a difference in weight between the students and TAs than the instructors and students. The ranks shifted again for the Community Centered lens with the TAs being more community-centered than the students and instructors. Though, the instructors were only slightly less community-centered than the TAs while the students gave less than a quarter of proportion to the lens.

While Table 4 shows how the groups differed among the four lenses, Table 5 compares the distances between the calculated four-dimensional points for each group.

The smaller the distance, the better the alignment. Details on the construction of points can be found in Chapter 3.

Table 5
Distances between Averaged Groups

Comparison	Distance
TAs and Instructors	0.088
Students and Instructors	0.135
Students and TAs	0.144

With a distance of 0.088, TAs and instructors were the most aligned in terms of the purpose of Calculus I labs. Thus, TAs and instructors viewed the purpose similarly among the four HPL lenses. Even though the amount of weight given to each lens differed, both TAs and instructors placed the most emphasis on the Community Centered lens followed by the Knowledge Centered lens and then Assessment and Learner.

The students were less aligned with the TAs and the instructors given that the distances for both comparisons are greater. There were more differences in how students distributed weight among the lenses. The students emphasized the Knowledge Centered lens the most out of the four lenses and then placed similar weight to Learner and Community while TAs and instructors emphasized Learner the least of the lenses. However, the students and instructors were similar in their proportions for Assessment Centered, and likewise, the students and TAs were similar for the weight given to the Knowledge Centered lens.

Purpose by Sections

While there were differences between the averaged groups of students, TAs, and instructors in terms of how weight was distributed among the four lenses, the distances between groups were not great. Thus, overall the groups were fairly aligned in how they viewed the purpose of Calculus I labs within the HPL framework. However, when the groups are averaged together, differences between groups in each section are diminished. Table 6 presents how the students (averaged together), the TA, and the instructor for each of the 12 sections weighted the four HPL lenses. One instructor taught both sections 4 and 9 (denoted 4/9 in the text). Four of the TAs were assigned two sections each (1/5, 2/3, 7/12, 10/11). Survey data of the instructors for section 10 and 11 is missing.

Table 6

Purpose of Lab by Sections within HPL Framework

Section	LC	KC	AC	CC	Section	LC	KC	AC	CC
#1					**#7**				
Students	0.186	0.321	0.229	0.265	**Students**	0.250	0.375	0.193	0.183
Instr.	0.250	0.250	0.250	0.250	**Instr.**	0.188	0.344	0.156	0.313
TA	0.188	0.250	0.188	0.375	**TA**	0.250	0.250	0.250	0.250
#2					**#8**				
Students	0.250	0.358	0.182	0.210	**Students**	0.213	0.331	0.175	0.281
Instr.	0.250	0.188	0.125	0.438	**Instr.**	0.125	0.250	0.375	0.250
TA	0.188	0.500	0.188	0.125	**TA**	0.188	0.250	0.125	0.438
#3					**#9**				
Students	0.246	0.293	0.242	0.219	**Students**	0.203	0.384	0.250	0.163
Instr.	0.125	0.438	0.125	0.313	**Instr.**	0.188	0.250	0.313	0.250
TA	0.188	0.500	0.188	0.125	**TA**	0.313	0.375	0.125	0.188
#4					**#10**				
Students	0.222	0.295	0.232	0.252	**Students**	0.293	0.330	0.245	0.134
Instr.	0.188	0.250	0.313	0.250	**Instr.**	-	-	-	-
TA	0	0.250	0.188	0.563	**TA**	0.188	0.250	0.125	0.438
#5					**#11**				
Students	0.194	0.316	0.214	0.277	**Students**	0.268	0.352	0.110	0.274
Instr.	0.063	0.375	0.438	0.125	**Instr.**	-	-	-	-
TA	0.188	0.250	0.188	0.375	**TA**	0.188	0.250	0.125	0.438
#6					**#12**				
Students	0.226	0.363	0.163	0.248	**Students**	0.250	0.344	0.244	0.163
Instr.	0.125	0.188	0.063	0.625	**Instr.**	0	0.375	0.313	0.313
TA	0	0.500	0.125	0.375	**TA**	0.250	0.250	0.250	0.250

Note: Survey data missing for instructors in labs 10 and 11. Sections 4 and 9 have the same instructor. Sections 1 and 5, sections 2 and 3, sections 7 and 12, and sections 10 and 11 have the same TAs. Abbreviations: Instructor (Instr.) Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC).

In each of the 12 sections, the students emphasized the Knowledge Centered lens the most out of the four lenses. This is consistent with all of the students averaged together. However, the other three lenses varied between the sections. The Learner Centered and Community Centered lenses were almost equally weighted by all of the students averaged together and were second and third, respectively, after the Knowledge Centered lens. But in some sections, students were the least learner-centered (1, 4, 5) or the least community-centered (3, 7, 9, 10, 12) of the four lenses. Some sections (2, 6, 8,

11) gave the Assessment Centered lens the least weight which is consistent with the overall averaged students. However, section 9 was the most assessment-centered after knowledge.

Even though the instructors cumulatively were the most community-centered of the lenses, only two sections (2,6) had the same trend. In both sections, almost half (0.438) and more than half (0.625) of the proportion was given to the Community Centered lens, which likely skewed the average towards Community. However, none of the sections' instructors ranked Community last. The Knowledge Centered and Assessment Centered lenses were second and third, respectively, for instructors on average, but some sections were the most knowledge-centered (3, 7, 12) or the most assessment-centered (4/9, 5, 8). Overall the instructors grouped together gave the least amount of weight to the Learner Centered lens. This is similar to six of the instructors individually with some giving no value or very little value (0.063) towards being learner-centered. It is important to point out that an instructor (1) was perfectly balanced among the four lenses.

For the TAs averaged together, the Community Centered lens was the highest ranked of the four lenses, which was also seen with four of the TAs individually (1/5, 4, 8, 10/11). Three of the TAs (2/3, 6, 9) were the most knowledge-centered instead, and one TA (7/12) was perfectly balanced among the four lenses. The Assessment Centered and Learner Centered lenses were given the least weight for the TAs cumulatively. This was consistent with the sections individually as six out of eight TAs were either the least assessment-centered or learner-centered. Two of the six TAs gave zero weight to the Learner Centered lens.

To see how the groups in each section compared to each other, Table 7 shows the distances between the students, the TA, and the instructor and the level of alignment in each section. Students are denoted with an ‘S’, TAs with a ‘T’, and instructors with an ‘I’. The comparison between the students and the instructor is denoted by ‘S – I’, the TA and the instructor by ‘T – I’, and the students and the TA by ‘S – T’. Alignment was determined by the distances calculated in the comparisons and is labeled with low, moderate, or high in the table. Chapter 3 contains a detailed description of how alignment was determined. Because instructor survey data was not available for sections 10 and 11, the S – I and T – I distances are missing, and alignment could not be determined.

Table 7
Distances and Alignment between Groups for Each Section

Comparison	Distance	Alignment	Comparison	Distance	Alignment
Section #1			**Section #7**		
S – I	0.099		S – I	0.152	
T – I	0.153	High	T – I	0.159	High
S – T	0.137		S – T	0.153	
Section #2			**Section #8**		
S – I	0.290		S – I	0.235	
T – I	0.451	Moderate	T – I	0.319	Moderate
S – T	0.177		S – T	0.185	
Section #3			**Section #9**		
S – I	0.241		S – I	0.172	
T – I	0.217	Low	T – I	0.265	Moderate
S – T	0.241		S – T	0.168	
Section #4			**Section #10**		
S – I	0.098		S – I	-	
T – I	0.385	Moderate	T – I	-	N/A
S – T	0.387		S – T	0.352	
Section #5			**Section #11**		
S – I	0.306		S – I	-	
T – I	0.395	Moderate	T – I	-	N/A
S – T	0.121		S – T	0.209	
Section #6			**Section #12**		
S – I	0.440		S – I	0.301	
T – I	0.424	Low	T – I	0.293	Moderate
S – T	0.296		S – T	0.128	

Note: Distances between the student and instructor and between the TA and instructor are not available for section 10 and 11 because of missing survey data for the instructor. As a result, alignment could not be determined for these sections. Abbreviations: Students (S), TAs (T), Instructors (I)

Due to small distances for S – I, T – I, and S – T, two sections (1,7) were designated with a high level of alignment. Six of the ten sections for which alignment was determined had a moderate alignment (2, 4, 5, 8, 9, 12). Section 2 had a large distance for T – I and a medium distance for S – I, while having a small distance for S – T. Thus, the instructor was misaligned with the other groups. This was the case for three other sections (5, 8, 12) where the students and the TA appeared aligned while the T – I and S – I distances were either medium or large. One section (4) had a similar case, but instead of the instructor, the TA was misaligned from the other groups due to large distances for T – I and S – T. The sixth moderate alignment section (9) had a medium distance for T – I and small distances for S – T and S – I, so the TA and the instructor were misaligned with each other. As a result, a moderate level of alignment was assigned. Two sections (3, 6) were given a low level of alignment. Section 3 had medium distances for S – I, T – I, and S – T, so all three groups were misaligned. For section 6, the instructor was misaligned due to large distances for S – I and T – I. However, there was a medium distance for S – T, so the students and the TA were not aligned as well. Hence, the alignment was deemed low. Out of the ten sections, three were selected for an embedded case study.

Embedded Case Study

To investigate how the views of the purpose align or misalign with the practices of lab, three sections were selected for observations. Each of the three cases were observed three times during the semester, and the TAs were interviewed following each observation. The next sections provide a summary of each lab and evidence from the observations and interviews as themes within the four lenses of the HPL framework. Section 7 was selected due to small distances for S – I, T – I, and S – T which qualified the section to be designated with a high level of alignment. For the observations, this section is denoted as Lab A. Section 5, referred to as Lab B, was chosen because the distances for S – I and T – I were large which indicated that the instructor was misaligned with the students and the TA. The third section selected was section 4 (or Lab C) due to large distances for T – I and S – T meaning the TA was misaligned from the instructor and the students.

Summary of Lab A

The lecture and the lab components both met twice a week. The instructor's syllabus indicated that lab by means of homework was worth 15% of the grade but contained no other information about the lab component. According to the TA, the instructor wanted the TA to "just make sure they understand all the homework problems" and to assign a homework grade at the end of the semester. The instructor also requested that the TA attend the lecture portion of the course to be able to know what was covered during class.

Typically during lab, the class worked on the section covered in lecture the day before, reviewed the previous lab's material, and then the students were quizzed on this older material. During an interview, the TA explained that instead of grading every homework problem like the instructor requested, the daily quiz was based off the homework and served as a way to check if the students were completing the homework. The TA also clarified that due to poor communication, the instructor was not aware of the daily quizzes. To begin the class, the TA usually worked an example problem on the document camera and then allowed the students to work on other problems in groups. As the students worked, the TA circled the room answering student questions and clarified concepts to the entire class based on student error.

Based on the observations, the practice of Lab A was balanced among the four lenses of the HPL framework. For the Learner Centered lens, evidence appeared in the themes of 'multiple teaching strategies' and 'addressing student needs'. The TA paid attention to the needs of the students and structured the lab to reflect those needs. The TA reviewed precalculus material as needed and focused on calculus as a whole which produced themes of ‘precalculus review’ and ‘Calculus I’ for the Knowledge Centered lens. The Assessment Centered lens was strongly present as the themes ‘summative assessment’, ‘formative assessment’, and ‘self-assessment’ due to the daily quizzes that allowed the students to revise their work and self-assess their understanding. The students were encouraged by the TA to work together inside and outside of the classroom which was facilitated by a Facebook page created by the TA for the purpose of communication. Thus, the Community Centered lens contained themes of ‘group work’ and ‘communication’. Each lens and its themes is discussed in detail in the section that follows.

While Lab A was selected due to the high level of alignment, there was some misalignment between the observed practice in the lab and the views expressed on the survey. Table 8 provides a summary of the survey results for Lab A.

Table 8
Summary of Lab A

Group	LC	KC	AC	CC	Distance		Alignment
Students	0.250	0.375	0.193	0.183	S – I	0.152	
Instructor	0.188	0.344	0.156	0.313	T – I	0.159	High
TA	0.250	0.250	0.250	0.250	S – T	0.153	

Note: Abbreviations: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC), Students (S), TAs (T), Instructors (I)

The students and the instructor were the most knowledge-centered of the four lenses, while the TA was perfectly balanced among the four lenses. The instructor weighted the Community Centered lens more than Learner and Assessment, while the students emphasized the Learner Centered lens more than Community or Assessment.

Lab A’s practice was balanced among the four lenses so the TA’s views were aligned with the practice. However, the students’ views were less aligned than the TA’s due to the students’ emphasis on the Knowledge Centered lens. With the daily quizzes and the amount of group work observed, the weight given to the Assessment Centered and Community Centered lenses by the students does not coincide with the practice. Similarly, the instructor heavily weighted both the Knowledge Centered and Community Centered lenses and ranked the Assessment Centered lens which lead the instructor's views to be misaligned with the practice. The ranking of the Assessment Centered lens was likely due to the instructor not being aware of the given daily quizzes.

Summary of HPL lenses.

***Learner Centered*.** Overall the TA is very learner-centered in the classroom and focused on the students. The TA frequently interacted with the students one-on-one and referred to each student by name. Through these interactions, the TA discovered students' needs and addressed issues as needed. Two themes emerged from the observations: multiple teaching strategies and addressing student needs.

Multiple teaching strategies. During class, the TA utilized different teaching strategies and techniques to try to help the students gain understanding and to help clarify confusing concepts. In every observation in which the TA presented problems on the document camera, the TA changed pen colors when drawing graphs or to show different steps in a problem. According to the TA, if the problems are long or difficult, the TA would take a photo and post it online so that students could have access to the image in color. The TA also mentioned that the students frequently commented on how much they appreciated the change in the pen color on evaluations.

The use of pen color was particularly evident in the second observation when the class was focused on approximating area under a curve. The TA illustrated the differences between using left and right end points by drawing both methods on the same graph using different colors for each. To demonstrate how increasing the number of rectangles improved the approximation, the TA drew two rectangles on a graph in one color and then added four rectangles in a different color. Through this, the student could see that having four rectangles would cover more space under the curve which would lead to a better approximation.

When asked about using multiple pen colors, the TA responded, "I always like to switch on each step that I'm doing something differently so they [the students] can kind of follow along…" The TA acknowledged that some students benefited from seeing content visually. During the interview, the TA revealed that the worksheet used during the first observation were not typical for the class. The worksheet contained five problems over the topics of critical points, local and absolute extrema. Given that the topic involved a lot of graphing, the TA decided to give the students a worksheet so "it would be easier for them to like go back and forth…being visual" to help them organize their work.

If the students were struggling with a concept, the TA would address the issue whether it was an algebra or calculus topic. If the issue persisted, the TA would try different explanations in order to help the students. During the second observation, the students seemed to really struggle with the new material, and in the follow-up interview, the TA explained the response as deciding "to stop doing the notation and just try to focus on the concept". Instead of using the finite sum notation, the TA switched to the geometric focus on how to find area of a rectangle. The TA tried multiple approaches to explaining the material such as using graphs to illustrate the idea behind the notation and focusing on the students' previous knowledge of finding area to help them make connections.

Addressing student needs. The TA was very aware of the needs of the students, structured the class with these needs in mind, and revised the agenda if needed. The agenda was provided for the students at the beginning of each class which details the structure of that day such as what topics are to be covered and listed due dates for assignments. One issue that emerged from the observations was with the students' lack of attendance in the lecture portion of the course. In the first observation, the TA began the class with a list of definitions and explained in an interview that it was because "at least half of them [the students] probably haven't even like seen it before." According to the interview, the TA attended the lecture component for about a month like the instructor requested before stopping due to coursework time constraints. During this month, the TA noticed that half of the students were not attending lecture and realized that without going over the definitions during lab, the majority of the students would be lost during class. While there was a quiz scheduled for the end of that class, the TA decided to postpone it because the students did not finish the worksheet and explained during the interview that "there were still so many people being unsure about it". The attendance issue was also evident in the second observation. Given the timing of the exam, the TA remarked in the interview, "I'm pretty sure not many people went to the lecture on Thursday after the test where they should have begun Chapter 5." As a result, the students really struggled with approximating area under a curve because they had not seen the notation before. The TA responded to this by focusing on the geometric concept instead and decided to revisit the notation during the next class.

Making sure the students felt comfortable in the classroom is something the TA strived to achieve. In the first observation, the last problem on the worksheet required students to switch notecards with other students in order to complete the table provided. The notecards had different functions written on each one, and the students had to fill out a row in the table by providing the domain, derivative, absolute and local extrema for each function. According to the TA, the reason behind the notecards was not only to encourage group work, but also to make the task less overwhelming. While having a list of all of the functions to fill out the table might be tedious to the students, the TA thought that just one notecard with one function at a time "doesn't look as overwhelming". While the TA tried to boost group work, the group work was not forced on students. During the interview, the TA elaborated, "I don't want to push anyone who is not comfortable because I know some people much rather work on their own skill sets…I don't want to make them [the students] socially awkward and then cause math anxiety at the same time."

Similarly, instead of having a quiz the day before and after the exam, the TA used the Quest in place of daily quiz grades. A Quest is a set of about twenty problems selected by the TA from old exams from other professors. The students selected ten to fifteen problems to complete and submit for grading worth two quiz grades. The TA explained the reasoning behind the Quest in an interview, "They're already freaked out about the other test, so I don't want to give them more assessments". The students got to select problems they were conformable with and use the Quest as a means of review.

Knowledge Centered. There is evidence of the Knowledge Centered lens in the observations and interviews with the TA, which can be classified under two themes:

precalculus and calculus. The TA made sure to stress important calculus concepts and definitions that were needed for the students to be successful and reviewed key topics from precalculus that underlined the calculus work. Through interactions with students, the TA identified the gaps of knowledge in the students and addressed these issues by reviewing or re-clarifying concepts.

Precalculus review. In all three observations, the TA reviewed algebra or trigonometry topics based on the needs of students. During the first observation, the students were working on graphing functions by using derivative tests to find local and absolute extrema. Based on interactions with students, the TA reviewed how to determine the end behavior of polynomial functions so students could correctly complete their graphs.

Similarly in the third observation, the TA went over precalculus concepts based on the problems on a mock final exam that the TA created for the students to use as a final exam review. As the students selected problems they had questions about, the TA provided the appropriate background needed in order to complete the problem. For example, the first problem on the final involved finding values of inverse trigonometric functions. As the TA completed the problem, the TA reviewed trigonometry functions and their properties and drew the unit circle as an aid. Another problem selected by a student required finding the asymptotes of a rational functions. After the TA finished presenting the problem, a student asked about oblique asymptotes which prompted the TA to discuss how to find horizontal asymptotes by comparing the degrees of the polynomials in the numerator and denominator.

Calculus I. As with the reviews of precalculus topics, the TA also made sure to review key calculus concepts. In the first observation, the class began with a review of the definitions of local extrema and absolute extrema because the TA was going to be using a lot of these new terms during class. Due to poor attendance in lecture, the TA stressed in an interview, “I’m going to make sure they know the definition” because terminology is important to performing well in calculus. The TA also put definitions on quizzes and repeated certain definitions in order to stress their importance even further. During an interview, the TA revealed, “I must have asked the definition of a limit at least three times before somebody got it completely right.” Similar to definitions, the TA also reviewed key concepts or theorems in class. The Mean Value Theorem was needed to complete one of the problems on the worksheet in the first observation, so the TA reviewed the theorem with the entire class prior to using it to complete a problem. In the second observation when the students were struggling with notation, the TA focused on the geometric representation, stressed the concepts behind the calculations, and used visuals to further help students make sense of the material.

Besides reviewing material for the topic at hand, the TA also made a point to stress end-of-course knowledge that the students would need to possess. During an interview the TA explained that if the class average was failing on a particular quiz, the students were allowed to complete corrections because “a majority of them did not get this concept…” The TA brought up the chain rule for derivatives as an example of something the students were struggling with on quizzes. “The chain rule is something that they’re going to use over and over…you’re going to need to know the chain rule for the rest of the semester and every other math class from now on out.” Thus according to the

TA, the quiz corrections served as a way for the students to work on understanding the concept without having to spend additional class time re-discussing the topic.

In the third observation, the goal of the class, according to the TA, was for the students "to ask questions on something that they were unfamiliar of everything that could be on a final". The review provided by the TA was the cumulative knowledge of the semester which the students should know for the final exam. To further the emphasis on what students should know by the end of Calculus I, the TA provided a handout on what the students were expected to know at the beginning of Calculus II. The handout covered a review of functions, limits, derivative rules, antiderivatives, and common student errors.

Assessment Centered. As a result of daily quizzes which provided the majority of the structure, the lab was fairly assessment-centered. However, the TA used different types of assessment to help the students in various ways. Three themes emerged from the observations and interviews: summative assessment, formative assessment, and self-assessment.

Summative assessment. The quizzes were written by the TA based off the textbook homework problems assigned to the students by the instructor. According to the TA in an interview, the lab was worth 10% of the students' grade which the instructor wanted to be determined by the homework. This statement conflicted with the 15% listed in the syllabus which could be the result of an issue in communication between the TA and instructor or an error made by the TA. Instead of grading all of the homework as requested by the instructor, the TA selected two to three problems from each assignment and modified them slightly for the quiz. Based on how students performed on the quiz, the TA was able to determine which students had completed the homework. The students were allowed to use their homework on the quiz, so if the students had completed the homework, they should not have struggled with the modified problems on the quiz according to the TA.

During the interview, the TA explained that the students were allowed to use any handwritten notes and homework on the quizzes because the students “would have open notes on their homework”. The TA wanted to create a similar testing environment to the students’ homework environment and as a result, wanted the students to have access to resources. The TA did not want the students “just to be stuck” on a problem or to give up as a result of forgetting a formula. Instead, the TA hoped having access to homework and notes on a quiz would encourage students to seek help during office hours or by going to tutoring.

In place of daily quizzes near an exam, the Quest is given to students with questions the TA had selected from old calculus exams which the TA clarified during the interview. According to the TA, this provided students with a chance to review the material that was going to be on their exam. The students were able to work together on the Quest and take it home to complete it using resources as needed.

Formative assessment. The quizzes and Quests not only acted as summative assessment, but also as formative assessment. The TA would address common mistakes found in students’ work and reviewed concepts that gave the students trouble. In the second observation, the TA went over common mistakes found on the second Quest like finding local and absolute extrema as well as how to determine where a function was increasing and decreasing. According to the TA, if issues with a particular topic persisted, the students were allowed to submit quiz corrections in order to reinforce the concept.

During the class, the TA also used formative assessment to gauge student knowledge. By interacting one-on-one with the students and answering student questions, the TA was able to tell how comfortable the students were with the material. When needed, the TA clarified concepts and reiterated ideas. In the first observation, the TA reminded students how to determine end behavior of functions. When the TA made a suggestion to the students to use their graphing calculators to check their work, the students were not able to do so, and the TA ended up demonstrating an example on the document camera. Through working with the students, the TA realized the students were not comfortable with the new material. In the interview, the TA explained the decision to move the summative assessment (the quiz) to the next class because the students "wouldn't have done well". The TA understood that students needed more time with the material prior to being assessed on it.

Self-assessment. Another theme from the interviews and observations was the TA's desire to help the students to self-assess their own understanding. In an interview, the TA explained that quiz corrections were used to help students self-assess their learning and to get them to understand the concept instead of spending extra class time covering the material again. The students could earn half the points back on a problem they missed if they reworked the problem and then wrote "at least one complete sentence explaining why they're confident that their new answer was correct and realized the error of their old answer". Through this, the TA tried to get the students to understand what they did not understand before and to encourage the students to self-assess.

In the interviews, the TA also referred to Quests and the mock final given on the last day in terms of students' self-assessment. On Quests, the students got to select which problems to turn in and as a result, were given an opportunity to assess what topics they were comfortable with and which ones they needed to revisit while studying for the exam. The TA also explained that the students could earn extra credit on the Quest by posting the solutions to Quest items online. According to the TA, this way the students were able to check their answers and to see solutions to the other problems posted by their classmates. Similarly, as seen in the third observation, the TA provided the students with a mock final in order for the students to begin preparing for the final exam. The TA expressed hope in the follow-up interview that given the mock final, the students would recognize topics that they had forgotten and to self-assess what they knew.

Community Centered. The TA tried to encourage the students to work together in various ways both inside and outside the classroom. As a result, there was significant evidence of a community found in the observations, which can be organized into themes of group work and communication.

Group work. Expressed during an interview, the TA wanted the students to collaborate as much as possible during lab in order to eliminate a competitive environment. In the first observation, the TA tried to directly encourage group work by handing out the function notecards which the students were supposed to swap amongst themselves. As stated in the follow-up interview, the TA hoped the students would compare their results "to be more social on the answers".

The TA revealed during an interview that partner quizzes and Quests were used as ways to facilitate group work and to encourage interactions between the students inside and outside of the classroom. According to the TA, partner quizzes have occurred in previous classes when there was a shortage of time or a difficult topic. The TA said the students worked faster with a partner "because somebody else was there to check their work or they weren't stuck". Working with a partner on a quiz improved the students' grades, and the TA hoped this would encourage students to work together outside of class. The TA explained, "I figured they would probably work together outside if it was just regular homework as well." Similarly, Quests were first given out during class, and students were instructed by the TA to work on it in groups. As a result, more than half of the students worked with a neighbor or within a small group during the observations. During an interview, the TA mentioned that collaboration between the students had increased over the course of the semester with the various assignments they were given.

Communication. Communication seemed to be something the TA valued in and out of the classroom and aimed to facilitate it in the lab as well. In all observations, there were numerous instances of students asking questions and interacting with the TA. The students seemed to feel comfortable asking the TA questions and working on problems with each other. The TA answered each student's questions when addressed in front of the entire class and when working with the students one-on-one. These interactions sparked discussions and encouraged the class or groups to work together. In an interview, the TA explained that due to the last observation being the last day of class, an opportunity was provided for the students to ask as many questions as possible on problems or topics they were unfamiliar with. The TA worked the problems the students selected, answered any questions that arose, and prompted students to ask more questions.

In order to communicate outside of the classroom, a Facebook page was created for the class by the TA. During an interview, the TA demonstrated the features of the Facebook page and explained the reason behind its creation: the TA wanted to be able to communicate with the students and for the students to communicate with each other. The TA expounded that for extra credit, students can post the solutions to Quest items on the Facebook page and leave comments on other students' work. The TA showed a recent post submitted by a student which contained a photo of the solution to a Quest problem, and then explained that if a solution is posted with an error, a student can "steal" the extra credit points by leaving a comment on the post pointing out the error. Reminders about due dates, photos of problems worked out during class, and sometimes suggestions on which definitions to review for upcoming quizzes were posted by the TA. The Facebook page seemed to be another way to facilitate the class to work together as well.

Lack of communication between the TA and the instructor was mentioned by the TA during the interviews. According to the TA, the instructor was hard to get in contact with after the TA stopped attending lectures and did not answer e-mails. As a result, the TA did not know what material was covered during lecture which affected the lab. The TA mentioned that the students noticed the lack of communication when the TA did not know where the instructor stopped in lecture. The TA stressed that the instructor did not seem to care what happened during the lab.

Summary of Lab B

Both the lab and lecture component met two times a week. According to the syllabus, a quiz was to be given every day in lab with the exception of test and review days which were listed on a tentative schedule provided. The syllabus also listed the time and place of the lab and included the contact information and office hours of the TA. In an interview, the TA explained that the instructor wrote the daily quizzes based on the assigned homework and expected the TA to grade them. Furthermore, the instructor wanted the TA to answer homework questions and work examples during lab in order to prepare the students for the quizzes.

As a result, the lab was centered on the homework assigned by the instructor and the quiz at the end of class. The students selected problems from the homework that they had struggled with and these problems became the focus of class discussion. The TA chose one problem at a time, and then either student volunteers or students selected by the TA presented steps to the problem on the board in front of the whole class. There was class-wide discussion of each problem with the TA clarifying key concepts or notation to the students. At the end of class, the students took the quiz over the topics covered in the homework.

From the observations, Lab B had evidence for all four of the HPL lenses. However, the Learner and Community Centered lenses were far more pronounced than the other two lenses with themes of 'students as individuals', 'instructional techniques', 'supportive environment', and 'discussion'. The TA gave personalized attention to each student and made sure to use whichever techniques were needed in order to ensure understanding. The classroom environment was receptive to students' questions, students presenting were encouraged by the TA and fellow classmates, and the class frequently discussed problems. The Knowledge Centered lens was evident with themes of 'conceptual focus' and 'calculus' due to the TA's emphasis on calculus concepts and the theory behind the homework problems. Daily quizzes and the TA's feedback provided the theme of 'formative assessment' to the Assessment Centered lens. The themes for each lens are detailed in the following section.

Lab B was selected due to the instructor's views being misaligned with the students' and the TA's views. The instructor's misalignment was also evident when the views were compared with the observed practice, and some misalignment occurred with the students and TA as well. A summary of the survey results is provided in Table 9.

Table 9
Summary of Lab B

Group	LC	KC	AC	CC	Distance		Alignment
Students	0.194	0.316	0.214	0.277	S – I	0.306	
Instructor	0.063	0.375	0.438	0.125	T – I	0.395	Moderate
TA	0.188	0.250	0.188	0.375	S – T	0.121	

Note: Abbreviations: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC), Students (S), TAs (T), Instructors (I)

In Lab B, out of the four lenses, the students were the most knowledge-centered, the instructor was the most assessment-centered, and the TA was the most community-centered. All three groups had the least amount of weight distributed to the Learner Centered lens with the TA weighting the Learner and Assessment Centered lenses equally.

The observed practice was first most in terms of Learner and Community Centered lenses followed by Knowledge and Assessment. Out of the three groups, the TA's views were the most aligned with the practice though there was some evidence for misalignment. The TA emphasized the Community Centered lens the most on the survey but ranked the Learner Centered lens last. This contradicted the learner-centered practice of the lab and the TA's views expressed during the interviews. The TA knew the students individually and each of their strengths and weaknesses. There was also some misalignment with the students' views and practice. The students overemphasized the

Knowledge Centered lens and deemphasized the Learner Centered lens even with the observed focus on the students as individuals. Consistent with the survey results, the instructor's views were misaligned with the practice. The instructor heavily weighted the Knowledge and Assessment Centered lenses which opposite of the observations. The instructor's views are consistent with the directions given to the TA at the beginning of the semester but do not match the actual practice of the lab.

Summary of HPL lenses

Learner Centered. During the observations and interviews, there were multiple ways in which students were given individualized focus, and the TA was very familiar with the students' knowledge, weaknesses and strengths. The TA used different strategies in class for each student to participate and really focused on student understanding. Two central themes arose from the data: students as individuals and instructional techniques.

Students as individuals. In the interviews, the TA frequently talked about the students individually. When asked about how the students worked together, the TA went student-by-student and discussed their participation in class like which students they work with or what issues they had. The TA seemed to know the students personally and how they performed in the class. During an interview, the TA explained that it was a personal goal to learn each students' name and to address each student by their name during class.

Throughout class, the TA selected individual students who had not volunteered to present on the board. The TA explained in an interview, "I think if I were to let just people volunteer and the same people talk, it would be the same three students who are very vocal." As a result, individual participation was encouraged by the TA. In the first observation, the three students selected by the TA to present had not been to the board yet during the semester as the TA revealed in an interview. In selecting these particular students, the TA hoped to encourage these students to be more vocal during class.

Student input was also valued in the class. When the TA presented a problem at the board, the students were encouraged to help and provide the next step. If a student suggested a step or a different method, their input was acknowledged and frequently used. For example, in the third observation, the TA finished a problem on the board using students' input and then asked if there was another method that could be used to complete the problem. On account of the expression involving a natural logarithm, a student suggested to use *e*, and the TA demonstrated this method to the class. Furthermore, during the observations, the TA made sure to answer each student's question even repeating what was said moments before.

Instructional techniques. In the lab, the TA utilized a "you, y'all, we" method for instruction which can be seen in all three observations. In an interview, the TA described how this method was explained to the students, "I want you to try it on your own, of course, just do your homework … but then there's a group in here, you guys … We'll put up a problem and someone has some questions but I'm still going to give you 'y'all' time to work together in groups and then 'we' as a group go over it." According to the TA, this technique allowed the students to work on their own understanding before sharing with a group or the class. The TA also encouraged students to come up with their own methods for approaching problems. In the third observation, the TA let the students use the unit circle instead of the triangle approach presented by the instructor. The TA explained during an interview that the trigonometric functions and their inverses were "really built off their [the students'] prior knowledge, like their pre-calculus knowledge" which is why the TA allowed the students to use a different approach.

Another aspect of the TA's instruction was the use of consistent notation with the instructor. The TA regularly attended the lecture portion of the course and actively tried to match the notation used by the instructor. The TA elaborated during an interview on this approach, "They [the students] are definitely getting used to the mathematical language in Calculus I and so if I could …make the burden a little less, and try to stay consistent, that's what I try to do." While students were presenting at the board, the TA was observed correcting their work in terms of notation if there were any errors.

To help students gain understanding, the TA used visuals to explain concepts. In the first observation when the students were trying to maximize the volume of a box and find the needed dimensions, the TA demonstrated how a flat piece of cardboard would need to be cut and folded into a box by taking a piece of paper and ripping the corners off. The TA used this visual to help students understand why the cuts needed to be congruent and how the length of the cuts would have to be restricted. The second observation also had evidence for use of visuals. In order to explain why the bounds need to change when doing a *u*-substitution integration problem, the TA projected a graphing calculator on the board and graphed the original function to be integrated along with the function found after *u*-substitution in order to emphasis how the area under each function changed if the bounds were kept the same.

Knowledge Centered. The Knowledge Centered lens was evident in the observations and interviews with the TA. In the classroom, the TA focused on students' conceptual understanding of calculus topics. Specific attention was paid to making sure the students used correct notation and were familiar with the terminology. The TA reviewed important topics with the students to make sure they were prepared for the quizzes. This is summarized with the themes of conceptual focus and calculus.

Conceptual focus. The TA made a strong effort to focus on the underlying concepts in the problems being discussed in class. During the interview, the TA explained that once students have the “big concepts”, the “plug and chug” of problems becomes routine which is “not the purpose of the class”. Specifically in the second observation, the TA wanted to revisit evaluating definite integrals using *u*-substitution because the students “have this little trick that they can do that will work out, but it takes away from the entire concept of what we're doing”. As a result, class time was spent reviewing definite integrals as a concept of finding area under a curve. The TA tried to visually show the students why changing the bounds was necessary for problems of this type to build on their conceptual understanding.

During the third observation, the students were taking the derivative of inverse trigonometric functions. In one problem, the chain rule for derivatives was needed followed by algebraic simplifying to get the solution listed in the back of the book. When the students were concerned about the simplifying, the TA stressed how certain steps in the problem demonstrate conceptual understanding of the chain rule which is what the TA looked for when grading quizzes.

Calculus. Besides focusing on conceptual understanding, the TA also wanted the students to be familiar with the proper notation of calculus and the vocabulary. In each observation, there were instances of the TA pointing out errors in student notation and discussing why certain notation was needed. With terminology, the TA explained in an interview, “I'm trying to build the concepts to tie in with each other, and so I'm like, ‘The integral, we are taking the antiderivative’." The TA repeated vocabulary terms during the discussion in class in order for the students to learn them.

The TA also reviewed important calculus topics during class as needed. For the example, the TA specifically selected a problem needing Newton’s method in the first observation because it was beneficial for the quiz. While working the *u*-substitution problem during the second observation, the TA reviewed the integral as finding the antiderivative and explained “the anti-power” rule. In the same class, the students struggled with how to evaluate definite integrals, so the TA went over the Fundamental Theorem of Calculus to explain why the upper bound went before the lower bound.

Assessment Centered. The Assessment Centered lens appeared through the theme of formative assessment. The TA’s knowledge of each student in the classroom helped with assessing their needs. The use of formative assessment happened during “y’all” time in the classroom as well as during quizzes. The TA also used graded quizzes and student questions in the lab and lecture to gauge where students were lacking understanding.

Formative assessment. In each observation, the TA used the “you, y’all, we” technique for instruction and assessment. The TA used the ‘y’all’ time when students were working in groups to gauge students’ understanding and progress on particular problems. Based on how the students were doing, the TA made decisions on what step is needed next or how much time to spend on the problem. In the first observation, the class discussed two optimization problems with one problem given much more class time. When asked why during the follow-up interview, the TA explained, “With the first one, when I was walking around, people were leaving things blank, and they weren’t really doing the ‘y’all’. So I … mixed the ‘y’all’ and ‘we’ together to try to get them more motivated to do the problem.” The TA had the students present parts of the problem at a time in order to help other students make progress on the problem. About the second problem, the TA said “I walked around and I saw most of them were doing it on their own, on their paper. And so, and they were talking in their group, so from what I was observing from them the ‘y’all’ part was a really strong.” Thus, the second problem was discussed less because the students had better understanding. During ‘y’all’ time, the students had an opportunity to receive feedback when working one-on-one with the TA or with other students. While the students were presenting, the TA corrected students’ notation and asked them questions about their work, so the students were given more feedback on their understanding.

According to the TA, quizzes and questions that arose in lecture were used to assess student understanding. When asked about the goal of the second lab observed, the TA replied, “I definitely wanted to address an issue I saw last quiz… And then there was something that they had asked in lecture the day before that tied into that.” The students were struggling to understand changing the bounds when working with *u*-substitution in definite integrals, so the TA made sure to address the problem during lab.

Formative assessment was utilized by the TA while the students were taking a quiz. During the quiz in the last observation, the TA noticed a problem in which the students might have difficulty with and circled around the room assessing the students’ progress on that problem. Based on their lack of work, the TA provided a hint to use a trigonometric substitution to the students. When asked about this during the interview, the TA responded, “I was thinking about it and I just know from prior labs of what we had been working on that the substitution wasn't very like strong. They would try to do just techniques that we had practiced or done, so I didn't want them to give up on the problem entirely." On account that using the substitution was key to completing the rest of the problem and the following problem, the TA decided to give the hint in order to see if the students could get the main concept of the problem rather than focusing on the first computational step.

When students turned in their quiz, they were automatically handed an answer key. The TA said during an interview, "I think it's like the feedback right away is really good…They [the students] want to self-assess immediately. And I have office hours for that after lab and that means that they're coming to my office hours, right after the lab, they're coming right away to discuss it." The graded quizzes were another way for the students to get comments on their work, and office hours served as time to get additional help.

Community Centered. In the lab, the sense of community was very strong. The TA encouraged students when they were presenting at the board, and the students were observed helping each other either at the board or in groups. A comfortable environment was developed in which the students felt at ease asking questions and engaging in class-wide discussion, which can be summarized into two themes: supportive environment and discussion.

Supportive environment. During the first observation, the TA selected a student to come to the board and encouraged him to use the "buddy system" for help. The student asked his classmates, and several students helped him to find the derivative of an expression. During the follow-up interview, the TA explained why the system was utilized in class, “I want them to feel like when they go up to the board that…it’s not a quiz, it’s not like you’re by yourself, so people can help.” When the next student was selected, she seemed nervous and overwhelmed about coming to the board, but the TA encouraged her and helped her to get started. Similarly, other students in the class helped her as well. This system of support was seen throughout each observation, and the TA was positive and reassuring to each student. In an interview, the TA expressed the pressure of thinking in front of an audience and wanted to make sure the students did not feel discouraged from learning. According to the TA, the students were told that “we’re here to learn, everyone makes mistakes and mistakes are my most favorite thing ever…because you learn from them.”

When not presenting at the board, the students worked on the problems on their own or in groups. There were discussions between the students on the problems, so the students received support from their classmates. Any questions the students had were either answered by the TA one-on-one or in front of the whole class. No questions were ignored or turned away, which helped to provide a supportive atmosphere for students’ learning.

Discussion. Each problem that was put up on the board was discussed by the class. When students presenting struggled, classmates provided directions or advised which step to take next. When a student had a question, sometimes another student, not the TA, provided an answer. When asked about the high level of communication in the class, the TA responded, “I definitely built that up. Instead of answering questions, I redirected it to another student.” The TA would ask other students what they thought about the question and would not tell students if they were right or wrong. As a result, the

TA said, “And so the discussion keeps going. And I don't want to try to answer…see who can answer and who can go through it [the problem].”

In the third observation, the class spent some time working on evaluating an inverse trigonometric function. The TA wanted to review a method taught by the instructor which involved the use of two right triangles, $30° - 60° - 90°$ and $45° - 45° - 90°$, and instructed the students to construct the unit circle based on the triangles. A student volunteered to draw the unit circle on the board from memory, but got flustered when the TA asked him to explain the process to the class. When asked why during a follow-up interview, the TA clarified why the explanation was important, “Because it's not only about them presenting it, it's also about the class.” The TA wanted the students to be able to follow the work put on the board, so the TA corrected students’ notation and had them direct their explanation to the class.

Student input was valued, and the TA frequently asked the students what steps to take or if other methods could be used. In the same inverse trigonometry problem seen in the third observation, after the class found the solution using the unit circle, the TA asked the class if there is another way to find the solution. One student mentioned “SOHCAHTOA” (a mnemonic device for remembering how to find trigonometric values of angles), and another student demonstrated to the class how to write the problem as $\cos^{-1}\left(\frac{1}{2}\right) = \theta$ so that $\frac{1}{2} = \cos\theta$. The TA acknowledged both contributions, and they were included in the class-wide discussion of the problem.

Summary of Lab C

The lecture component for the course met twice a week while the lab met three times, so the students had class every day during the week. The syllabus for the course explained that the quizzes and exams take place during lab and provided a tentative schedule. Attendance in both lab and lecture was stressed in the syllabus with the student allowed to miss a certain amount of classes before absences started to affect their grades. According to the TA in an interview, the instructor wanted the TA to write the quizzes based off of the assigned homework problems and then grade the quizzes. The TA explained that no direction was given by the instructor in terms of the structure of the lab and felt unprepared on how to organize class time.

During the observations, the structure of the class largely depended on the material and students' needs. If the students had a large amount of questions, the TA would spend more time reviewing the material and working problems on the document camera. Otherwise, the students were given time to work on problems on their own or in groups. Sometimes there was a combination of group work and TA presentation with the TA working an example and then the students working on a similar problem in groups. The focus of the classes was based on the homework assigned by the instructor and the daily quiz given about two out of the three class days a week.

While the practice of Lab C had evidence of all four HPL lenses, the lenses were not balanced. The TA structured the lab based on the vocalized needs of the students as a whole. As a result, the Community Centered lens contained the most evidence with themes of 'group work' and 'receptive environment'. The students were able to work together and communicate their concerns to each other and the TA. The needs of the students stemmed from their focus on understanding the calculus concepts behind their homework problems, so the Knowledge Centered lens followed the Community Centered lens with a theme of 'calculus review'. Due to frequent homework quizzes given by the

TA, the Assessment Centered lens was evident with a theme of ‘formative assessment’. The quizzes allowed the TA to assess the students’ understanding and to provide feedback. The lens with the least evidence was the Learner Centered lens on account that the TA was did not emphasize the students as individuals during the observations and interviews. However, each student was able to voice their concerns to which the TA always responded, so the theme of ‘student needs’ was evidence for the Learner Centered lens. Detailed descriptions of the themes are provided in the next section.

Lab C was selected due to the views of the TA being misaligned from the views of the students and the instructor. In contrast, the TA’s views were more aligned with the practice than the views of the instructor. However, the views of all three groups had at least some misalignment with the observed practice. The views are summarized with Table 10.

Table 10
Summary of Lab C

Group	LC	KC	AC	CC	Distance		Alignment
Students	0.222	0.295	0.232	0.252	S – I	0.098	
Instructor	0.188	0.250	0.313	0.250	T – I	0.385	Moderate
TA	0	0.250	0.188	0.563	S – T	0.387	

Note: Abbreviations: Learner Centered (LC), Knowledge Centered (KC), Assessment Centered (AC), Community Centered (CC), Students (S), TAs (T), Instructors (I)

The students gave more weight to the Knowledge Centered lens than the other three lenses, and the instructor did so for the Assessment Centered lens. However, both groups were similarly community-centered and were the least learner-centered among the lenses. While the TA was also least learner-centered of the lenses, a weight of zero was given to the lens by the TA which was much less the instructor (0.188) and the students (0.222). The TA also weighted the Community Centered lens the heaviest of the four by proportioning more than half of the points.

From the observations, the practice of Lab C in terms of the four HPL lenses was ranked in the following order: Community, Knowledge, Assessment, and Learner. The students' views were the most aligned with the practice given how weight was distributed among the four lenses. However, instead of ranking the Community Centered lens first as with the observed practice, the students emphasized the Knowledge Centered lens the most. While the TA's views ranked the lenses in the same order as the practice, the TA gave no weight to the Learner Centered lens which was in conflict with evidence for that lens. Thus, the views of the TA were slightly misaligned with the practice. Of the three groups, the instructor's views were least aligned with the observed practice but not drastically. The instructor gave the most weight to Assessment Centered lens which was not the lens with the most evidence, but the other lens were consistent with the observations. The Assessment Centered lens was ranked first most likely due to the instructor scheduling the quizzes and exams during lab time.

Summary of HPL lenses.

Learner Centered. The Learner Centered lens was present in the sense that the students guided the configuration of the lab. Depending on students' needs, the TA adapted the structure of the lab and the problems presented in class. Students' questions decided how much time was allotted per activity, and the TA modified problems based on students' comprehension. This can be summarized with the theme of student needs.

Student needs. In every observation, the students asked the TA about a specific concept. The student either wanted to see an example of a particular type of problem, or the TA responded to a student question by working a problem to illustrate a concept. In the first observation after the TA reviewed antiderivatives using a polynomial function as an example, a student asked to see an example with a trigonometric function because he was having trouble with them. The TA replied by selecting an appropriate problem from the book and working it as an example. During the second observation, a student asked the TA about definite integrals and negative area under the curve. The TA answered the student question and then decided to work an example to further explain the concept. A similar instance happened during the third observation when a student brought attention to a specific problem that required the use of L'Hôpital's Rule on logarithmic functions. The TA wrote a hint on the board, but the student still struggled and asked to see the problem worked in its entirety. After presenting the problem on the document camera, the TA asked the student if she was comfortable with the solution. When the student still seemed unsure, the TA reassured her by giving an overview of using L'Hôpital's Rule.

Students' questions not only guided which problems the TA selected and worked, but also helped structure the class time. In the first observation, there were few questions brought up by students, so the TA gave them time to work on a problem set in groups. As the students worked, they were able to bring up questions one-on-one with the TA. Conversely, there was a quiz scheduled for the end of class during the second observation, and the students asked question after question in order to prepare for the quiz. As a result, the TA worked problems leading up to the quiz and gave no time for independent group work. In the last observation, there was no quiz, but student questions arose. Thus, the TA structured class time where students had time to work on the problems and the TA presented problems based on students' needs. During an interview, the TA informed that the quizzes are typically at the beginning of lab, and that class time is given for a review, which is "entirely prompted by the students", prior to the quiz.

When asked how much class time the review takes up, the TA responded, "It's usually just kind of tailored to whatever they [the students] are asking." If the material was harder for the students and as a result there were more questions, the TA gave more time for a review to cater to the needs of the students.

Furthermore, the TA understood that different students had different needs in the class. In the third observation, the TA instructed students who had completed the homework to work on a different set of problems. When asked about this, the TA explained, "I wanted to give an opportunity for them to have something to work on as well that was new but also beneficial to the idea of learning L'Hôpital's Rule." The TA also revealed during the interview that there was a group of students who often finished ahead of the class. In order to keep them focused, the TA gave the group harder problems to work on to keep them engaged with the material.

Besides responding to student needs in the moment, the TA also tried to anticipate what students' needs might be ahead of time based on the interviews. According to the TA, for the first observation, the TA believed the students would come to class with the homework mostly completed, so the TA made up a problem set similar to the homework for the students to work on. The TA thought that the material would not be difficult for the students, so class time was structured to allow the students to discuss problems in groups. Another example of this was observed during the third class. Towards the end of class time, the TA selected a problem from the textbook similar to a problem in the students' homework. During the follow-up interview, the TA explained that the problem was "very different from the rest of the problems" and had predicted that the students would struggle with it when working on their homework. The problem was worked by the TA during class in order to help the students complete their homework problem later on.

Knowledge Centered. Based on students' vocalized needs or the needs the TA anticipated, the TA reviewed important calculus concepts and tried to make connections for the students by stressing the relationship between derivatives and antiderivatives. Thus, the evidence for the Knowledge Centered lens emerged as the theme calculus review.

Calculus review. In each of the classes observed, the TA reviewed important concepts to help students progress through that day's material. At the beginning of class in the first observation, the TA reviewed antiderivatives which were covered in lecture only the day before. Derivatives and antiderivatives were compared, and the TA emphasized their relationship by working examples. This concept was revisited during the second observation. Based on the frequency of student errors, the TA reviewed the derivative and antiderivative relationship for trigonometric functions sine and cosine before presenting a trigonometric u-substitution problem for a definite integral. In this same observation, the TA stressed how to select an appropriate u for the substitution and strategies on selecting the easiest method for completing a problem. Students' questions prompted the TA to review how to treat the bounds of integration for definite integrals when u-substitution is necessary. During the follow-up interview, the TA explained that because the students had just come back from Thanksgiving break, the third observed class began with a review of derivatives in order to prepare the student for L'Hôpital's Rule. The TA elaborated, "So the students were getting settled back into the classroom and so we were talking a little L'Hôpital's Rule. So I spent some time in the beginning of the lab kind of refreshing taking derivatives and so that they would remember." After the class reviewed all of the derivative rules, the TA presented a problem using L'Hôpital's Rule and then reviewed the algebraic way to compute the limit. When a student was confused about a problem presented by the TA, the TA reviewed the concept behind L'Hôpital's Rule with the entire class.

Assessment Centered. The Assessment Centered lens was observed through quizzes in lab and the TA's interactions with students. The TA responded to students' questions and structured class based on students' needs. A single theme emerged from the observations and interviews with the TA: formative assessment.

Formative assessment. The TA used students' questions in lecture and in lab, as well as students' quizzes to assess how the students understood the material. As expressed during an interview, the TA attended lecture about once a week and would make notes on questions the students had for the instructor. The TA expounded, "…when I see them [the students] fall apart in lecture, I know what I need to cover in lab." According to the TA, the class often ended with the TA working a difficult problem that was selected based on interactions with the students during group work. The TA said in an interview, "I get the question over and over and over again. So sometimes when I see that we're running out of time, I'll say 'OK, let's talk about problem number 40" and I'll get up and I will walk them through problem number 40."

Before a quiz was given, the TA reviewed the content with the students. The time given for the review was based off the number of student questions. If the TA felt that the material was harder for the students, then the concepts were given a longer review in order to help the students. In the second observation, there were many students' questions, so the TA ended up working several problems to clarify. As a result, the quiz was held at the end of class. In the same observation, based on the frequency of student errors in class and on previous quizzes, the TA reviewed the derivatives and antiderivatives for sine and cosine functions on the chalk board and left this review un-erased for the quiz. When asked the reason behind this, the TA responded, "…they [the students] are really struggling with when goes this negative come into this *u*-substitution. So, they're confused between the connection between taking the derivative of a trig function and the antiderivative of a trig function…" The TA wanted the students to be able to focus on the *u*-substitution rather than get stuck on a negative sign. The students were also able to use resources on a quiz such as the unit circle. The instructor allowed the students to use a unit circle for exams, so the TA felt that the students should have the same resources in lab during quizzes. After a quiz, the TA would go over the problems on the quiz if needed based on students' reactions. During an interview, the TA said, "…if they [the students] have questions or they seem unhappy, I'll, you know, do a key for them right there."

Community Centered. The lab was very community-centered through the students working together, interactions with the TA, and an interactive environment catered to the students. The observations can be summarized through two themes: group work and receptive environment.

Group work. In an interview, the TA expressed that the students were encouraged to work together and were given the opportunity to do so "fairly regularly, maybe once a week". Out of the three observations, only the first one occurred on a day devoted to group work. The TA created a problem set for the students to work on and projected the set to the front of the room. As the TA circled around the room answering students' questions, more than half of the class worked in groups or with a neighbor. One student worked problems on the chalk board while explaining each step to several other students and recalling topics from lecture. This group went through multiple problems during class and paused when needed to make sure everyone understood. When asked about this "student teacher", the TA responded, "There are actually a couple of them [students]…who will get up with a piece of chalk and start working on the board and explaining what they're doing to other students which I think is really good." The TA explained that the students are comfortable working with each other and "do tend to work together" as a class.

Receptive environment. When the TA presented problems to the class, the TA frequently asked for students' input for the next step or the solution. The students seemed to offer their ideas readily, and wrong answers were not discouraged by the TA, which created an environment in which the students could easily participate. In the second observation, the TA discussed how to select an appropriate u for the u-substitution method for integration and selected a problem to work based on a student's question. The students were asked to select u for the problem and gave several wrong suggestions to the TA. The TA responded by guiding the students away from the wrong selections without oppressing them. This behavior was also seen during the third observation when the class reviewed derivative rules in order to prepare for using L'Hôpital's Rule. The TA demonstrated several of the rules with examples while asking the students for the solutions. Each students' response was written on the document camera including incorrect ones. The TA used the wrong answers to discuss mistakes with the class and carefully corrected the students.

Besides providing input while the TA worked problems, the students also felt comfortable asking the TA questions either one-on-one or in front of the class. Any time the students were given time to work on a problem individually, the TA walked around the room responding to any student with a raised hand. When the TA worked problems in front of the class, students were able to ask questions about a step shown or about the calculus concepts being discussed. The TA always responded to the student's questions and when appropriate selected a problem to work to clarify. In the second observation, a student asked about negative area under a curve from integration. The TA answered the question and used a problem from the book to illustrate the concept.

Students were also able to ask questions before or after a quiz. The TA said during an interview, "I'll do a small review like if they ask a question or if they want to know something…" The amount of time given for the review depended on how many questions the students had, and while the quiz was typically at the beginning of class, enough questions from students could have the quiz moved to the end of class. This was observed during the third observation when the students were struggling with using the *u*-substitution method for integration. In an interview it was revealed that the TA was also receptive to students' questions after a quiz, and said, "…if they [the students] have any questions about it at all, I'll work through the quiz." This environment allowed for the students to contribute to the class, and the TA tailored the structure based on students' input.

Summary of Results

Based on the survey data, observations, and interviews, the following research questions will be answered in this section:

1. What is the purpose of Calculus I labs according to students, teaching assistants, and instructors?
2. How are the views of the purpose aligned or misaligned between the groups?
3. How are the views of the purpose aligned or misaligned with the classroom practices of the lab?

The purpose of labs will be described for all students, TAs, and instructors based on the survey results. Then the alignment of the views will be discussed between the three groups cumulatively and by section. Using the observations and interviews, along with survey data, the alignment of views and practice will be determined for the three embedded case studies: Lab A, Lab B, and Lab C.

Purpose of Calculus I labs. For students, the purpose of Calculus I labs was to gain knowledge. Students were mostly knowledge-centered and viewed the lab as a place to make sense of calculus topics. The lab served as a way for the students to connect the theory of lecture to the homework problems. In terms of the lab being focused on learner, assessment, and community, the students were almost balanced among the three in their views, but considered assessment the least purposeful. Based on the survey, the students regarded the lab as where they had the material explained to them in a way they understood and to be able to comfortably ask questions to the TA or other students. The lab did provide students with the opportunity to assess what they knew about calculus, but not necessarily to demonstrate to the TA or instructor this knowledge.

The purpose of labs, according to TAs, was in terms of community and knowledge. The TAs believed the lab offered students a comfortable learning environment in which students could actively participate and ask questions at ease. The lab also allowed the students to connect the lecture to the assigned homework problems. The TAs regarded the purpose of Calculus I labs as being less learner- and assessment centered, but did think of it as a place for students to have the material more personally explained and to receive feedback on their understanding.

The instructors viewed the purpose of lab as being focused on community followed closely by knowledge. The environment should be supportive and allow for students to participate and to ask questions. The lab provided an opportunity for the students to make connections between lecture and homework, as well as think mathematically during activities. While less so than community and knowledge, the instructors also considered the purpose in terms of assessment, mainly for students to be assessed on their knowledge and to receive feedback on their work. The purpose of Calculus I labs was least learner-centered for instructors, though they believed the lab is a place for each student to have the material explained to them meaningfully.

Alignment of views. When all of the students, all of the TAs, and all of the instructors were considered together as three groups, the views of the purpose of Calculus I labs were aligned between groups. TAs and instructors were the closest aligned in their views by regarding the purpose in terms of community and then knowledge. Both groups were much less learner- and assessment-centered for the purpose, though instructors weighted assessment heavier while TAs regarded the two equally. The students differed from the instructors and the TAs as the purpose of lab for them is mostly in terms of knowledge. However, this difference is not enough for the views to be considered misaligned. The students regarded the purpose first in terms of knowledge, but learner, community, and assessment came next, respectively, and were given similar emphasis. The amount of weight given to the purpose being knowledge-, community- , and assessment-centered is comparable for students and instructors. Thus, students and instructors were fairly aligned in their views of the purpose of Calculus I labs. For TAs and students, the views were less aligned, but not significantly. TAs believed the purpose was to be more community driven than the students did, and the students emphasized learner and assessment in terms of the purpose. However, both groups give similar weight for a knowledge-centered lab, and overall students and TAs were suitably aligned in terms of their views.

If each section of Calculus I is considered independently, alignment of views varied between groups and sections significantly. Of the ten sections in the analysis, only two sections were strongly aligned. In each of these section, the students, the TA, and the instructor had similar views as to the purpose which is why the section as a whole is aligned. Six sections were moderately aligned for the purpose of Calculus I labs. For four of the six sections, the instructors' views differed from the students' and the TAs' views, so the sections were considered to have some misalignment. As for the other two sections that were moderately aligned, the TA's view of the purpose of lab diverged from the views of the students and the instructor creating misalignment in one section. In the other section, the instructor and the TA had opposing views which negatively affected the alignment of the section. Finally, two of the ten sections were misaligned in their views. For one of these sections, the instructor conflicted strongly with both the students and the

TA in terms of the purpose of lab. The students and the TA also had dissimilar views, so the section had a low level of alignment. The other section had nearly the same amount of misalignment between all three groups. The students, the TA, and the instructor had different views of the lab in terms of its purpose.

Alignment between views and practice. To determine how aligned the views of the purpose of lab were with the practice in lab, three sections were selected for observations followed by interviews with the TAs. Lab A was selected due to the high level of alignment between the students, the TA, and the instructor. The other two labs, Lab B and Lab C, were selected because the instructor and the TA, respectively, were misaligned from the other two groups.

***Lab A*.** The observations held evidence that the lab was balanced in terms of learner, knowledge, assessment, and community. The TA understood when students were struggling with the materials and used different methods including visuals to help students. Important calculus topics were stressed during class and in quizzes, and connections were made with students' prior knowledge. Through daily quizzes and Quests, the students received feedback, and the TA encouraged students to self-assess their own understanding. The students were also encouraged to work together in and outside of class, and were able to communicate with each other using the class's Facebook page.

The TA's views of the purpose of lab were aligned with the observed practice due to the TA being balanced for learner, knowledge, assessment, and community. This was consistent with the observations and interviews with the TA. The TA considered the needs of the students when structuring activities and utilized different strategies to help students learn. The TA made sure to focus on important concepts in calculus and strived to prepare students for future courses and learning. Formative assessment was used by the TA to provide students with feedback, a change to revise their work, and to self-assess their learning. The TA actively fostered a community in which students could communicate with each other, ask the TA questions, and work together in a comfortable environment. Thus, the practice of the lab was aligned with the TA's views because the TA provided the structure for the lab.

The students' views were less aligned with the practice as a result of the students being more knowledge-centered and less community- and assessment-centered. The students emphasized that the purpose was to connect lecture to the homework, make sense of new topics, and demonstrate what students needed to know by the end of the course. While there was evidence for these purposes, knowledge was not observed to be the most important component over the other three. Students were observed actively participating in class and working with their classmates, but did not perceive these occurrences as the purpose of the lab. Similarly, the students were frequently quizzed, and feedback was given, though not much emphasis was given to these as the purpose. The students' views did align with practice as the students did ask the TA questions at ease and had the material explained to them in a way they understood. Hence, there was some alignment and misalignment with the students' views and the practice of the lab.

The views of the instructor had some alignment with the practices of the lab. The instructor considered knowledge and community to be the main purposes for the lab. Helping students make sense of calculus topics and homework problems, as well as working in groups with classmates, were considered the strongest purposes for the lab by the instructor. These purposes were observed, but were balanced with learner and assessment. The instructor did not stress for the students to have the material explained in a way they understood or for previous knowledge to be applied to new topics. Similarly, the instructor did not consider the lab as a way to provide an opportunity for quizzes, while daily quizzes were observed. Overall, the instructor's views of the purpose of lab were slightly misaligned from the practice.

***Lab B*.** From the observations, learner and community had the strongest evidence. Each student was considered as an individual learner and encouraged to participate in the class. The students actively discussed the topics with the TA and each other during class and worked with each other. The instructional technique of 'you, y'all, we' helped to facilitate these activities. With a daily quiz, assessment was also observed because the structure of the lab was catered for the quiz. While the quiz was a summative form of assessment without access to resources, the TA frequently used formative assessment to gauge the students' level of comprehension and to provide feedback. There was also evidence for knowledge though with less emphasis. The TA focused on strengthening the students' conceptual understanding of calculus topics.

The observations of practice were somewhat aligned with the views of the TA. The TA emphasized community above all and considered lab to be a supportive environment for the students to feel comfortable asking questions and working in groups. However learner was given less value than what was observed. The TA did not consider the purpose to be for students to utilize previous knowledge for new calculus concepts even though this was observed in class. Furthermore, the TA viewed the lab more in terms of knowledge than of assessment and did not think the purpose was for students to demonstrate their knowledge. In each observation, the students either displayed their thinking by working a problem on the board or by participating in the discussion. Therefore, there was some misalignment between the views of the TA and the practice of the lab.

For students, the purpose of the lab was foremost knowledge-centered which contradicted the emphasis in the observations. Students viewed the lab as a place to help them make sense of new topics and homework, as well as figure out what they needed to be able to do by the end of the class. However while the TA did focus on homework and stressed conceptual understanding of calculus topics, the focus was not a summative, end-of-course one. On the other hand, the students' views and observations in terms of community and assessment were similarly weighted. Students thought the purpose for lab was to be able to ask questions in a supportive environment, to be quizzed, and to receive feedback, which were frequently observed. As far as the purpose being learner-centered, the students were less aligned with their views and practice. The students did think the purpose was for them to have calculus explained in a way they understood, but did not consider their personal contribution to the class as important. This challenged the individualized focus to each student by the TA in terms of participation in the class. Thus, there is alignment and misaligned between the views of the students and the observed practice in lab.

The views of the instructor were strongly misaligned with the practice. The instructor considered the purpose to be in terms of first assessment and then knowledge with community and learner given very little consideration. Students should be assessed through quizzes, given feedback on their work, and connect the theory in lecture to the homework with an emphasis on summative knowledge. The assessment observed was less focused on summative knowledge, and formative assessment was frequently used by the TA during lab. The instructor did not regard the students' individual participation as being part of the purpose, nor the students having a comfortable environment in which they worked in groups. This contrasts with the strong observed emphasis on the student as an individual and the facilitation of group work and discussion. The TA developed a comfortable environment for the students by being supportive and encouraging cooperation. As a result, the instructor's views were misaligned with the practices of the lab in terms of the purpose.

Lab C. The lab was observed to be catered towards the students. Students' questions guided the TA in the selection of problems and the structure of the class. Communication allowed for the TA to make decisions and the students frequently asked questions, so the lab was more community-centered than learner, knowledge, or assessment. However students' questions were an attempt to make sense of the calculus concepts and to understand the homework problems, so the purpose was also observed in terms of knowledge. Similarly, the weekly quizzes kept the students' questions tailored to the material they were going to be assessed on. Thus, the lab was also observed in terms of assessment though less than knowledge. Though when the TA used students' questions to guide the lab, there was not a particular emphasis on students to contribute to the classroom personally. Therefore the emphasis on purpose was observed to be least learner-centered though still present.

For the TA, the views were mostly aligned with the observed practice in terms of ranking the four lenses, but not as much as far as the amount of weight placed on each lens. The TA considered community to be the main reason for the purpose and emphasized community much more than knowledge, assessment, and learner in that order. The purpose of lab was for students to have a comfortable environment in which they could ask questions and actively participate, which is consistent with the observed practice. Less than half as much weight was given to knowledge even though knowledge was observed to be the guiding force for students' questions. The TA did not believe lab should help students make sense of new topics, but this was precisely how students approached the TA with questions. While the TA did think the purpose of lab was for students to receive feedback, the purpose of lab was not for the students to be quizzed on the material which contrasts with the weekly quiz given. The majority of the misalignment came from the purpose in terms of learner. The TA encouraged students to use their previous knowledge to help them with the material and allowed individuals' questions to guide the class. However, the TA did not view the purpose of lab as being learner-centered at all. Hence, overall the TA's views were somewhat misaligned with the practice.

The students' views of the purpose were fairly aligned with the practice. While students considered the purpose to be more knowledge-centered than community-centered, the purpose was less assessment focused and even less learner which is consistent with the observations. For students, the purpose was to connect the theory from lecture to the homework problems and to understand new topics. The students also thought the lab should be a comfortable environment in which they can ask questions and work in groups. Both views, in terms of knowledge and community, were supported with the observed practice. The purpose was less assessment-centered for students, but consistent with the observations. The lab's purpose was for students to be quizzed on what they knew and to self-assess their learning. The students' views were least learner driven even though the students considered the purpose of lab was to have the material explained in a way they understood and to apply their previous knowledge to new topics. Due to the students' views being consistent with the observations, the views were mostly aligned with the practice.

The views of the instructor are somewhat aligned with the practice observed. The instructor considered the lab more in terms of assessment followed by knowledge and community equally. Thus, the lab served as a place where the students were quizzed in order to demonstrate what they knew, to self-assess, and to receive feedback. While the students were quizzed on a fairly regular basis, knowledge and community were observed to have more emphasis than assessment. The instructor did view the lab as a supportive environment where students can work together and ask questions, as well as make connections between lecture and homework in order to understand the new calculus concepts. These views were consistent with the observations. The emphasis given to learner was similar for the instructor's views and the observed practices, though the instructor did not regard the purpose as having the students utilize previous knowledge to help with new calculus topics. Therefore, as a whole, the instructor's views were moderately aligned with the practices of the lab.

Conclusion

In summary, students, TAs, and instructors viewed the purpose of Calculus I labs differently among the four lenses of the HPL framework. The differences were more apparently when the views were considered within each section of Calculus I. While there was some alignment of views of the purpose between groups of participants, the majority of the sections were misaligned in terms of the purpose of the lab component. Furthermore, the practice of lab was generally not aligned with the views expressed by students, TAs, and instructors. These results have implications on classroom practice, preparation of instructors and TAs, and departmental policies which will all be discussed in Chapter 5. The following chapter contains a summary of results positioned within the literature and provides suggestions for future research.

CHAPTER 5

DISCUSSION

Introduction

To investigate the purpose of Calculus I labs, a case study design was utilized to focus on a single public university in central Texas. During the course of one semester, all Calculus I sections were included in the sample. The instructors, TAs, and students were surveyed to determine their views on the purpose of Calculus I labs. These views were framed within the HPL framework, which is comprised of four lenses: Learner Centered, Knowledge Centered, Assessment Centered, and Community. The survey results were used to construct four-dimensional points for each of the participants using the four lenses. Once the points were established, distances between points were calculated to determine how the participants' views were aligned or misaligned. Based on the alignment of views, three cases were selected using a maximum variation sampling for an embedded case study. These sections were observed three times during the semester using a developed observation protocol (CLOP), and each observation was paired with a follow-up interview with the observed TA. The observations and interviews were conducted to determine if the stated views of the purpose of lab were aligned with the observed practice in the classroom.

This chapter summaries the results of the study and positions the findings within the body of research in the field. Implications of the findings will be discussed and suggestions for future research will be given.

Summary of Findings

Purpose of Calculus I labs. The study found that the views of the instructors, TAs, and students varied as to the purpose of Calculus I labs. In terms of the four lenses of HPL framework, the instructors and the TAs favored the Community lens, while the students most emphasized the Knowledge Centered lens. Among the other three lenses, the students were almost balanced but weighted the Assessment Centered lens least in terms of the purpose of lab. Instructors and TAs were far less balanced among the other lenses than the students. Following the Community lens, the instructors and TAs selected Knowledge with TAs giving the lens close to the same weight as Community. The instructors gave the least amount of weight to the Learner Centered lens of the four lenses, and TAs ranked the Learner Centered and Assessment Centered lens last and with equal weight.

When the instructors, TAs, and students are grouped by section and not considered collectively, the views of the purpose change. Of the nine instructors, only two emphasized the Community Centered lens as the purpose, which was seen with the instructors as group. The six of the instructors selected to give the most weight to either the Knowledge Centered or Assessment Centered lens. Only one instructor was perfectly balanced among the four lenses. While the Learner Centered lens varied in rank among the instructors, it was never given the most emphasis and ranked last for a majority of the instructor with one instructor giving no weight to the lens. The trend was very similar for the TAs considered by section. Collectively, TAs weighted the Community Centered lens above the other three lens, but only three out of the eight TAs did so individually. Of the remaining five TAs, four emphasized either Knowledge Centered or Assessment

Centered, and one TA was perfectly balanced among the four HPL lenses. Majority of the TAs did rank the Learner Centered lens last among the lenses as seen with the TAs as a group, and two TAs gave zero weight to the lens. The students in each section weighted the Knowledge Centered lens above the other three lenses, which is consistent when the students are considered as a group. However, the students by sections were not as nearly balanced among the other three lenses as all of the students combined. After the Knowledge Centered lens, the next lens given the most weight varied among the sections with each of the three lenses represented as the next lens. Only 2 of the 12 sections were close to being balanced among the four lenses.

Alignment of views. When viewed as groups, the instructors, the TAs, and the students varied in how weight was distributed among the four lenses of the HPL framework in terms of the purpose of labs. However, these differences were not significant enough to cause misalignment. The study found that instructors and TAs were aligned in their views of the purpose of Calculus I labs because the lenses were weighted similarly by both groups. The students regarded the purpose more in terms of Knowledge than Community and as a result, were less aligned with the instructors and with the TAs. Nevertheless, the three groups were deemed to be in alignment with each other on the purpose of Calculus I labs.

Conversely, when the views of the instructor, the TA, and the students were considered by section, there were significant differences in the perceived purpose of Calculus I labs. Out of the ten sections for which alignment was determined, only two sections demonstrated a high level of alignment among the groups. Six of the ten sections had a moderate level of alignment meaning some but not all of the groups were aligned.

Of these six sections, the TA and students were aligned in four of the sections, and the instructor was aligned with the students in one of the sections. The sixth section had misalignment between the instructor and the TA. A low level of alignment was determined for two out of the ten sections due to the misalignment between all three groups.

Alignment between views and practice. Three sections were selected for an embedded case study based on the alignment of views on the purpose of Calculus I labs. One section, titled Lab A, was selected due to a high level of alignment. The other two sections were selected due to some misalignment between groups. Lab B was selected because the instructor was misaligned from the students and the TA, and Lab C was picked due to misalignment with the TA.

Of the three sections selected for observations and interviews, only Lab A was observed to be balanced among the four HPL lenses. For this section, the TA was perfectly balanced among the lenses on the survey which was supported by the observations and interviews. While the instructor and students were considered to be aligned with the TA in terms of the views of the purpose, their views were less aligned with the observations of classroom practice. Lab A featured multiple types of assessment, as well as an emphasis on group work and communication. However, of the four lenses, the students put the least emphasis on the Community Centered lens and weighted Assessment similarly. For the instructor, the Assessment Centered lens ranked last of the lenses which was likely due to the instructor not being aware of the daily quizzes and other classroom practices. According to the TA, there was a lack of communication with the instructor.

While evidence for all four lenses was observed in Lab B, the observations and interviews with the TA revealed the lab to be more in terms of the Learner Centered lens and the Community Centered lens than the other two lenses. Students were treated as individuals and their individual input was valued during classroom-wide discussions which frequently occurred. Consistent with the observations, the TA heavily weighted Community on the survey. However, the Learner Centered lens was ranked last (along with the Assessment Centered lens) which contradicts both the observations and the TA interviews. The instructor's views of the purpose of lab were misaligned with the views of the students and the TA. Because the instructor was heavily knowledge- and assessment-centered (little weight was given to the Learner Centered and Community Centered lens), this misalignment also occurred with respect to the observations. The students' views were more aligned with the classroom practice than those of the instructor though not perfectly. The Community Centered lens was emphasized by the students in terms of the purpose of lab, but the students ranked the Learner Centered lens last.

Lab C also was observed to contain elements of all four HPL lenses, but less so than the other two labs. The TA catered the classroom practices to the vocalized needs of the students, so Lab C was primarily community-centered in its practices. The Knowledge Centered lens was secondary to the Community Centered lens and was noticed by the students' focus on knowledge when expressing their needs to the TA. For Lab C, the Learner Centered lens ranked last among the lenses due to a lack of emphasis on the students individually. The surveys revealed the TA to be misaligned with the students and the instructor in terms of the purpose of lab. However, the TA's views were aligned with the observed practices. The TA strongly emphasized the Community Centered lens while giving no weight to the Learner Centered lens. Similarly, the Learner Centered lens was ranked last by both the instructor and the students, but the students weighted the lens with nearly the same as the Assessment Centered and Community Centered lens. In fact, the student were more balanced among the four HPL lenses than the instructor and the TA. However, the students' views were still slightly misaligned from the observed practices, but only due to their emphasis on the Knowledge Centered lens above Community. Likewise, the instructor's views were somewhat misaligned with practice. The instructor considered the purpose of lab to be more in terms of assessment, which is likely due to both the quizzes and exams taking place during the lab.

Discussion of findings. The HPL framework is comprised of four overlapping lenses and was established to aid in the development of highly effective learning environments. The four lenses need to be present and balanced in order to create the desired learning environment (Bransford et al., 2000; Bransford et al., 2002). The learning environment is affected by the beliefs teachers hold (Pajares, 1992), so these beliefs or views must also be balanced among the four lenses. As seen with the results, the views of the purpose of Calculus I labs not only varied among the instructors, the TAs, and the students but also were not balanced among the four HPL lenses. Only one instructor and one TA were perfectly balanced among the lenses. One of the lenses, Learner Centered, was not considered in terms of the purpose at all by one instructor and two of the TAs.

While the views held by teachers or TAs may contradict the observed practice in the classroom (Goertzen et al., 2010; Fang, 1996; Lin et al., 2013; Speer, 2001), views that are not balanced in terms of the HPL framework may negatively affect the balance of lenses in the classroom practice. This could limit the learning environment for the students instead of creating a highly effective one. As seen with the three embedded cases, not all classrooms were observed to be balanced among the four lenses of HPL.

What occurs in the classroom is not only influenced by the teacher's beliefs (Pajares, 1992) but also by others, such as the principal, fellow teachers, and students (Davis et al., 1993; Kilgore et al, 1990). Therefore, the views of the instructor, the TA, and the students all affect the practices of the classroom and can affect the TA's instructional decisions. Because labs are set up under an overseeing instructor, the views of the instructor were observed to directly affect the lab classroom. In two of the three observed labs, there were daily quizzes which were mandated by the instructor, and the TAs were instructed to focus the lab towards preparing the students for these quizzes. In all three labs, there was a significant focus on the homework assigned by the instructor either due to the directions of the instructor or due to the quizzes being based directly off the homework. The views of the instructor were not the only ones that were observed to affect classroom practice. During an interview, one of the observed TAs expressed concern about a lack of preparation and experience in order to determine the structure of the lab. As a result, the students played a key role in how that TA structured the classroom practices. While the other two TAs did keep students' needs in mind when planning the lab practice, they structured their labs based on previous experience and relied less on the students for guidance.

As Lin et al, (2013) and Goertzen et al. (2010) reported, the TA's views on instructional decisions may conflict with the observed practices. This was only partially consistent with one of the observed labs. While the lab classroom was determined to be very learner-centered, the TA's stated views on the survey conflicted with the observations. However, the TA's stated views during the interview were found to be supportive in terms of the learner-centered nature of the observed classroom practice. The other two observed TAs did not conflict between their views and the observed practices. Therefore, the study found that the viewed expressed by the TAs during the interviews were in agreement with the practices of the lab.

The views of the instructor and the students affect classroom practice, so the alignment of the views between the TA, the instructor, and the students is crucial. If the different groups are considered as members of an organization, then systematic agreement is necessary in order to effectively achieve the organization's goals (Semler, 1997). If the goal is to create a highly effective learning environment, then the members must be in agreement. Thus, the instructor, the TA, and the students must be aligned in their views of the purpose of Calculus I labs, and furthermore, these views must be balanced among the four lenses.

When all of the instructors, all of the TAs, and all of the students were considered as three groups, their views were aligned. However, the sections of Calculus I work independently of each other. So when the views were considered by sections, each section was not aligned. In fact, only two of the ten sections are found to be aligned between the views of the instructor, the TA, and the students. Among the other eight sections, six sections were somewhat aligned and two of the sections were misaligned. Of the six sections that had some alignment, the instructor's views were found to be misaligned with the students and the TA in four of the sections. One of these four sections was selected for the classroom observations. While the instructor's views were not aligned with the TA or the students, they did not appear to affect the views of the TA or the classroom practice. Another one of the somewhat aligned sections was also selected for observation but on account of the TA being misaligned with the instructor and students. In this section, the TA reported a lack of experience and preparation, and little guidance from the instructor. This likely affected the classroom practice and could be the reason behind the misalignment of views.

The third of the observed sections was selected due to the alignment of views between the instructor, the TA, and the students. However, the observations revealed that the TA's views were aligned with the observed practice in the lab, but the instructor's views were misaligned. During an interview, the TA reported that communication with the instructor was very difficult which could have affected the alignment. Therefore, alignment of views between the instructor, the TA, and the students may not be enough to ensure alignment between the views and between the views and practice. From the sections selected for observation, communication between the instructor and the TA's level of experience could affect the alignment of views and the classroom practice.

Implications

In the past couple of years, poor graduation rates for STEM majors have been brought to national attention, and calculus has been considered a roadblock to graduating more STEM majors since the 1980s. Therefore, Calculus I as a course must strive to achieve an effective classroom learning environment in order to better benefit the students. The HPL framework stresses the need for balance among its four lenses because it is necessary in the creation of highly effective learning environments. The present study revealed a lack of balance among the four lenses of the HPL framework in both the views of the instructors, TAs, and students, and the classroom practices in the lab portion of the Calculus I course. Furthermore, the instructors, the TAs, and the students differed in theirs views as to the purpose of Calculus I labs, which led to the views being misaligned with the observed practice.

At the university selected for this study, there is currently no department policy on Calculus I labs. The lecture and lab components of the Calculus I course are left for the individual assigned instructors to organize. While there is a general department syllabus for the course, there are no guidelines similar to the HPL framework nor a stated purpose for the lab component. Thus, the organization of the lab classroom is typically given to the instructor's assigned TA to manage. The present study revealed the TA's classroom decisions and classroom practice are affected by both the instructor's and students' views. While all graduate TAs are required to attend a training workshop before the beginning of the fall semester, this workshop focuses on the department's developmental mathematics program. As one of the TAs in the study pointed out, there was a lack of preparation in terms of how the lab component of Calculus I should be structured. Communication was also an important factor for the TAs. One TA complained about the difficulty of communicating with the instructor, and the other two stressed the importance of communication.

Therefore the study has some implications for the organization of Calculus I classes and for TA training. Departments should make guidelines for instructors and for TAs in terms of how Calculus labs should be structured and to encourage communication among the persons involved in the course. Having a specifically stated purpose for the lab component could help to provide balance among the four HPL lenses and to align the views of the instructors, TAs, and students. Furthermore, inexperienced TAs need additional guidance on instructional practices which could help to create the desired effective learning environment.

Limitations

This study focused on a single university in central Texas which offered a lab component to Calculus I courses. The structure of the course included a lecture component taught by an instructor and a lab component taught by a TA with the same group of students attending both components. Thus, the results of the study can only be generalized to universities with similar structure in place. While some of the results may be extended beyond the scope of this particular university, any generalizing must be done cautiously.

The survey given to all students, TAs, and instructors in this study was developed by the researcher based on the HPL framework and interviews from the pilot study. The intention for the survey was to gather the views of the participants on the purpose of Calculus I labs. However, there is no guarantee that the survey accurately gathered the views on account that no method was utilized to corroborate the views. Only the TAs in the selected embedded case were interviewed which allowed for the comparison of views expressed in the survey and those expressed during interviews. The views were consistent for two out of three TAs which suggests that the survey could be improved to better gather the views of the purpose in future studies.

The three sections selected for the embedded case study were chosen based on maximum variation sampling and preliminary survey analysis. While the three cases demonstrated notable differences, a section with a low level of alignment was not selected. Therefore, the embedded cases do not necessarily reflect all of the variation among the sections.

Lastly, the researcher solely conducted the observations and interviews and analyzed the data. As with any qualitative data analysis, there was some level of personal bias due to the researcher making decisions on the interpretation of the data.

Future Research

This study brought up issues of balance among the four lenses of the HPL framework and of alignment between students, TAs, and instructors. In order to create a highly effective learning environment, the four lenses need to be balanced in practice as well as in the held views of those who affect the practice of a classroom. Further studies are needed on how to achieve balance in views and in practice, as well as investigate which factors influence balance. When several groups are involved in the instructional decisions of a classroom, their views must be aligned in order to achieve the desired goal of student learning. While this study highlighted misalignment between the views of instructors, TAs, and students, additional studies should aim to determine how alignment can be improved. The sections selected for embedded case study provided some insight into why misalignment might occur. However, a more tailored study is needed to investigate which factors affect alignment.

As a result of a case study methodology, the results can only be generalized to similarly structured Calculus I courses at similar universities. Additional research is needed to better understand how the structure of a Calculus I course affects the views held by students, TAs, and instructors, and if this structure can influence the alignment of views.

While this study focused only on Calculus I labs, other mathematics courses as well as science courses include a lab component. These results provide some insight on how students, TAs, and instructors view the lab component and how their views compare. Similar studies focused around different courses, especially in the sciences, could provide further valuable understanding on how different involved groups view the same component of a course.

APPENDIX SECTION

APPENDIX A: Pilot Interview Protocol

Interview Protocol

Student Interview Questions

1. First time taking calculus? Year in school? Major?
2. Have you taken any other labs before? If so, which ones?
3. Describe a typical day in your calculus lab.
4. What do you learn in lab? How is this different, if at all, from what you learn in lecture?
5. Where do you learn the most calculus? (i.e. in lecture, lab, home, tutoring, etc.)
6. Is attendance stressed by the TA and/or professor? How so?
7. How often does the professor mention the lab? Describe how lab is mentioned.
8. In your own words, explain the purpose of the lab.
9. What do you think is the overall purpose of calculus labs?

TA Interview Questions

1. Tell me about your lab. Describe a typical day.
2. Explain the professor's influence on what happens in lab.
3. How does the professor stress or discuss lab portion of the course?
4. Describe the attendance policy in lab. Who developed the policy?
5. In your own words, explain the purpose of the lab.
6. What do you think is the overall purpose of calculus labs?

Instructor Interview Questions

1. Describe how you envision a typical day in lab.
2. What is the attendance policy in lab?
3. Do you mention lab during lecture? If so, how?
4. In your own words, explain the purpose of the lab.
5. What do you think is the overall purpose of calculus labs?
6. Do you find labs to be an important component of calculus instruction? Why or why not?
7. Describe the guidance or direction that you give to your teaching assistant.

APPENDIX B: Pilot Observation Protocol

Name of TA:_____________ Date and Time:____________ No Students Beginning of Class:____

Events	Type	Notes
0-10min	Problem Selection o Student o TA o Lecturer Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		
11-20min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		

Events	Type	Notes
21-30min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		
31-40min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		

Events	Type	Notes
41-50min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		
51-60min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		

Events	Type	Notes
61-70min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		
71-80min	Problem Selection o Student o TA o Instructor Material Covered o Lecture Review o Precalc Review o Supplementary Interaction o Student Ques o TA response o 1-1 Student arrive late Student leaves early	
Eng Check		

No Students End of Class:______

Level of TA:________________ Degree Being Earned:___________________

ADDITIONAL NOTES

APPENDIX C: Student Survey

The Purpose of Calculus I Labs – Student Survey

Read the following 16 statements and consider which ones represent the purpose of Calculus I lab in your opinion. You are given a total of 16 points to distribute among 16 statements however you would like (assign a value between 0 and 16 to all items). You must use all 16 points. Please make sure the points add up to 16 by including a total count at the end.

The purpose of lab is….	Points
1. to provide an opportunity for me to contribute personally to the lab classroom.	____
2. for the TA to be aware of and encourage my individuality and culture.	____
3. for me to have the material explained in a way that I understand.	____
4. for me to use my previous knowledge to apply it to new calculus topics.	____
5. to connect the theory of lecture to the problems in the homework.	____
6. to make sense of new calculus concepts.	____
7. for me to understand what I need to know and be able to do by the end of the course.	____
8. for me to participate in activities that help me think mathematically.	____
9. for me to assess what I know and don't know about calculus.	____
10. for me to demonstrate what I know to the TA or the instructor.	____
11. for me to get feedback from the TA or the instructor on my work or understanding.	____
12. for me to be quizzed or tested by the TA or the instructor about what I have learned.	____
13. to provide an environment where I can actively participate.	____
14. to have a supportive and comfortable learning environment.	____
15. to be able to ask the TA or other students questions at ease.	____
16. to work in groups and discuss ideas with my classmates.	____
Total Points:	____

APPENDIX D: TA Survey

The Purpose of Calculus I Labs – Teaching Assistant Survey

Read the following 16 statements and consider which ones represent the purpose of Calculus I lab in your opinion. You are given a **total** of 16 points to distribute among 16 statements however you would like (assign a value between 0 and 16 to all items). You must use all 16 points. Please make sure the points add up to 16 by including a total count at the end.

The purpose of lab is….	Points
1. to provide an opportunity for students to contribute personally to the lab classroom.	____
2. for me to be aware of and encourage my students' individuality and culture.	____
3. for the students to have the material explained in a way that they understand.	____
4. for the students to use their previous knowledge to apply it to new calculus topics.	____
5. to connect the theory of lecture to the problems in the homework.	____
6. to make sense of new calculus concepts.	____
7. for the students to understand what they need to know and be able to do by the end of the course.	____
8. for the students to participate in activities that help them think mathematically.	____
9. for the students to assess what they know and don't know about calculus.	____
10. for the students to demonstrate what they know to me or the instructor.	____
11. for the students to get feedback from me or the instructor on their work or understanding.	____
12. for the students to be quizzed or tested by me or the instructor about what they have learned.	____
13. to provide an environment where students can actively participate.	____
14. to have a supportive and comfortable learning environment.	____
15. for the students to be able to ask me or other students questions at ease.	____
16. for the students to work in groups and discuss ideas with their classmates.	____
Total Points:	____

APPENDIX E: Instructor Survey

The Purpose of Calculus I Labs – Instructor Survey

Read the following 16 statements and consider which ones represent the purpose of Calculus I lab in your opinion. You are given a **total** of 16 points to distribute among 16 statements however you would like (assign a value between 0 and 16 to all items). You must use all 16 points. Please make sure the points add up to 16 by including a total count at the end.

The purpose of lab is….	Points
1. to provide an opportunity for students to contribute personally to the lab classroom.	____
2. for the TA to be aware of and encourage the students' individuality and culture.	____
3. for the students to have the material explained in a way that they understand.	____
4. for the students to use their previous knowledge to apply it to new calculus topics.	____
5. to connect the theory of lecture to the problems in the homework.	____
6. to make sense of new calculus concepts.	____
7. for the students to understand what they need to know and be able to do by the end of the course.	____
8. for the students to participate in activities that help them think mathematically.	____
9. for the students to assess what they know and don't know about calculus.	____
10. for the students to demonstrate what they know to me or the TA.	____
11. for the students to get feedback from me or the TA on their work or understanding.	____
12. for the students to be quizzed or tested by me or the TA about what they have learned.	____
13. to provide an environment where students can actively participate.	____
14. to have a supportive and comfortable learning environment.	____
15. for the students to be able to ask the TA or other students questions at ease.	____
16. for the students to work in groups and discuss ideas with their classmates.	____
Total Points:	____

APPENDIX F: Calculus Lab Observation Protocol (CLOP)

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

Name of TA: __________ Date/Time: ________ Enrollment: ____ No. Students: ____

Time	Tally	Notes
0-10 min Late ☐ Early ☐	Problem Selection: ☐ Instructor ☐ TA ☐ Student(s) Problem Presentation: ☐ TA ☐ Student(s) Content: ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary Interaction: ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1 Group Work: ☐ None ☐ Unstructured ☐ Structured	
Engagement Check: Structure:		
Time	Tally	Notes
10-20 min Late ☐ Early ☐	Problem Selection: ☐ Instructor ☐ TA ☐ Student(s) Problem Presentation: ☐ TA ☐ Student(s) Content: ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary Interaction: ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1 Group Work: ☐ None ☐ Unstructured ☐ Structured	
Engagement Check: Structure:		

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

Time	Tally		Notes
20-30 min Late ☐ Early ☐	<u>Problem Selection</u> ☐ Instructor ☐ TA ☐ Student(s) <u>Content</u> ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary <u>Group Work</u> ☐ None ☐ Unstructured ☐ Structured	<u>Problem Presentation</u> ☐ TA ☐ Student(s) <u>Interaction</u> ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	
<u>Engagement Check</u>: Structure:			

Time	Tally		Notes
30-40 min Late ☐ Early ☐	<u>Problem Selection</u> ☐ Instructor ☐ TA ☐ Student(s) <u>Content</u> ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary <u>Group Work</u> ☐ None ☐ Unstructured ☐ Structured	<u>Problem Presentation</u> ☐ TA ☐ Student(s) <u>Interaction</u> ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	
<u>Engagement Check</u>: Structure:			

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

Time	Tally		Notes
40-50 min Late ☐ Early ☐	**Problem Selection** ☐ Instructor ☐ TA ☐ Student(s) **Content** ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary **Group Work** ☐ None ☐ Unstructured ☐ Structured	**Problem Presentation** ☐ TA ☐ Student(s) **Interaction** ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	

Engagement Check:

Structure:

Time	Tally		Notes
50-60 min Late ☐ Early ☐	**Problem Selection** ☐ Instructor ☐ TA ☐ Student(s) **Content** ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary **Group Work** ☐ None ☐ Unstructured ☐ Structured	**Problem Presentation** ☐ TA ☐ Student(s) **Interaction** ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	

Engagement Check:

Structure:

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

Time	Tally		Notes
60-70 min Late ☐ Early ☐	Problem Selection ☐ Instructor ☐ TA ☐ Student(s) Content ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary Group Work ☐ None ☐ Unstructured ☐ Structured	Problem Presentation ☐ TA ☐ Student(s) Interaction ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	
Engagement Check: Structure:			

Time	Tally		Notes
70-80 min Late ☐ Early ☐	Problem Selection ☐ Instructor ☐ TA ☐ Student(s) Content ☐ Calculus Review ☐ PreCalculus Review ☐ Supplementary Group Work ☐ None ☐ Unstructured ☐ Structured	Problem Presentation ☐ TA ☐ Student(s) Interaction ☐ Student Question ○ TA Response ○ Student Response ☐ TA Ellicit Questions ☐ TA/Student(s) 1-1	
Engagement Check: Structure:			

CALCULUS LAB OBSERVATION PROTOCOL (CLOP)

TA Title: __________ Degree: ______ No. Students: ____

Additional Notes:

Reflective Notes:

Assessment:

APPENDIX G: First Observation Interview Protocol

TA Interview Protocol – First Round of Observations

General Questions

1. Thank you for taking the time to talk with me and letting me observe your classroom. Let's talk about the class I observed. Can you describe the class to me? Was this a typical structure to the class?
2. How much influence did the instructor have in the class I observed? How much influence does the instructor typically have over the lab classroom?
3. Do you attend the lecture portion of the course? How frequently do you communicate with the instructor? Do you e-mail or meet regularly?

Lab-specific Questions

Lab A

1. Materials –

When I came into the classroom, I noticed you had an agenda on the overhead that described what was due and what will be covered. Is this something you prepare for each class? Have you been doing this for the entire semester or was this something that developed during?

You also had a printed list of definitions you put on the overhead which included a visual of a graph. Is this typical? Do the students get access to this later?

When you worked on the overhead projector, you switched pen colors. Can you tell me why you do this? Do the students have access to copies of your notes later?

2. Problem Selection –

You had a worksheet for the students prepared for the class. How common is this? Describe to me how you select the problems on the worksheet.

For #5 on the worksheet, the students had to fill out a table based on function notecards you passed out. They were instructed to switch notecards with other groups. Do you use these notecards often? Explain to me this technique.

3. Group Work –

The students were instructed to work on the worksheets in groups. Some of them grouped with their neighbor(s) and some worked alone. Do you encourage them to work together? Or to consult other students?

4. Quizzes –

Tell me about the quizzes. Who writes them and which problems are typically included? How is grading and recording of the grades done? Do the students get an answer key?

The students were told they could use their worksheets on the quiz. Is this usual for the class? What is your reasoning behind this decision?

You mentioned quiz corrections. How does this work and why do you allow corrections?

5. Class Focus –

As class went on, it seems that the focus of the students wore off. Some of the students were on cell phones and others had their laptops out. Does this pose a problem in the class? Do you ever go over the class assignment at the end or have students present?

A few students left early and that seemed to signal to others that the class was over and more packed up. Is this a typical way for the class to end? Or do you usually end the class?

Lab B

1. Problem Selection –

The first problem was written by a student(s) on the board when you walked in. Is this common? Who usually selects the problems the class works on? If you select the problem, what is the reasoning behind your selection? When were these topics covered in lecture?

2. Problem Presentation –

I noticed the first problem was worked out by several students with each student contributing to a step towards the solution. You selected the students by name to come to the board. Can you explain to me your decision in having this structure? How do you select the students?

You also worked a few problems yourself. Why was there a switch in presentations?

3. Collaboration/Group Work –

You encouraged the students to work together and use the “buddy system” when students are at the board working. How did the “buddy system” come into place? How frequently do the students use the “buddy system” when they are at the board? Do the students usually work in groups or collaborate?

4. Interaction with students –

I saw that you circle around the room and go up to students individually. Describe how you interact or try to interact with your students. What do you hope to accomplish with this?

One student was very anxious while working on the board, and another was worried about not knowing how to do the next step to the problem. It seems like you tried to encourage students and make them feel as comfortable as possible. What can you tell me about that?

5. Quizzes –

Tell me about the quizzes. Who writes them? How is grading and recording of the grades done?

I also noticed you hand the students an answer key to the quiz as they turn their quizzes in. Why do you provide them with this right after?

Lab C

1. Problem Selection –

You began the class with a review of antiderivatives and showed two examples. A student mentioned having trouble with trig functions, and one of the examples you did was finding the antiderivative of a trig functions. Did you have the example ready ahead of time or were you responding to the student in your selection?

A set of problems were put up on the overhead projector for the students to work on. Can you talk me through your process of selecting these problems?

2. Quizzes –

Tell me about the quizzes. Who writes them and which problems are typically included? How is grading and recording of the grades done? Do the students get an answer key?

I heard you mention a "pizza promise" in regards to quiz grades. Can you explain to me what that meant?

3. Group Work –

After you put problems up, the students began to work. Some of them grouped with their neighbor(s) and some worked alone. Do you encourage them to work together? Or to consult other students?

I noticed one student in the back who took a teaching role and worked out several examples with two other students. Other students tuned in from time to time. Is this a common occurrence? He seemed to really try to make sure the other students (especially the girl) were getting it. Can you tell me more about this dynamic?

4. Class Focus –

You have a couple of students who seem to frequently ask you questions and take up the majority of your time. How do you feel about that? Do you try to manage your time between students or is this not really an issue in the class?

As class went on, it seems that the focus of the students wore off. Do you ever go over the class assignment or have students present?

A few students left early and that seemed to signal to others that the class was over and more packed up. Is this a typical way for the class to end? Or do you usually end the class?

APPENDIX H: Second Observation Interview Protocol

TA Interview Protocol – Second Round of Observations

General Questions

1. Thank you for taking the time to talk with me and letting me observe your classroom again. To refresh both of our memories, can you describe today's class for me?
2. Did you have any goals for the class? If so, what were they? How successful was the class to you in terms of attaining those goals?
3. How much influence did the instructor have in the class I observed?

Lab-specific Questions

Lab A

1. Problem Selection –

You selected a problem from the book (#2) to work out for the students on the overhead, and then gave them a similar one (#1) to do in groups. Can you explain your reasoning behind your problem selection?

2. Notation –

It seemed that the students were having a lot of trouble with the new material. As you went around the room answering questions, it seemed like you recognized the issue was with notation. How do you typically handle situations like this?

3. Group Work/ Class Focus –

It seemed like the class worked really well in groups today and remained on task. Was this typical for the class? Do you feel that this has improved over the course of the semester?

4. Quizzes –

Tell me about the quiz today. For example, why did you do a quick review of antiderivatives before the quiz? What could the students use on the quiz (homework, notes, etc.)?

You gave the students a little over 20 minutes to complete it, and a majority of the students were done in 10 minutes. How did you plan the length of the quiz time-wise?

Lab B

1. Technology –

From a previous quiz, you seemed to realize that the students were having trouble understanding the concept behind changing the bounds after *u*-substitution. You decided to graph the original function and the *u*-substitution function. Was this something you planned ahead of time? Can you talk to me more about this? Do you try to incorporate technology often?

2. Community –

I noticed several students calling each other by name, and some encouraged students who were presenting (e.g. "Go Kelly!"). Can you comment on this? Was this something you actively tried to encourage?

Several times during the class there were discussions over the concepts. Sometimes you would lead the discussion, but other times, the students would keeping the conversation going amongst themselves. Was this something present at the beginning of the semester or did it evolve during the semester? Is this something you tried to facilitate?

Another thing I noticed was that a student asked you to explain the "anti-power rule" for antiderivative. Is this a phrase introduced by the instructor or by you? Or was this a term the student came up with?

3. Quizzes –

I noticed one of the problems on the quiz was identical to a problem presented in class. Since you see the quizzes ahead of time, do you ever encourage the students to select certain problems? Or pick some for them? Or do you completely let them lead the course of the lab?

You mentioned cheating to the entire class and that you had spoken to the instructor about this issue. Can you tell me more about this?

Lab C

1. Class size –

The first thing I noticed was the class size. There were only 9 students missing (from the original number enrolled), and the students actually ran out of places to sit. Why do you think so many students were present today? Is this usual for the class?

2. Problem Selection –

You selected and worked a total of three problems today. Can you talk me through your selection process for these problems?

3. Quizzes –

Tell me about the quizzes. I noticed one of the problems had the *u* provided for the *u*-substitution. How did you select these problems?

I also noticed the unit circle was put up on the overhead for the duration of the quiz and the sine/cosine derivatives and antiderivatives were left on the board. Can you explain the reason for this?

4. Group Work –

Opposite of what I observed last time, today's lab had no group work. Why was the class structure different today?

5. Class Focus –

I noticed a couple of the students in the back were very vocal during the first half of the class. As the class went on, their focus wore off, but they seemed to have a good grasp of the material. The student next to me was making snarky comments about other students' questions and seemed inpatient with the speed of your work presentation. Do you ever have an issue with any of these students? Do you ever have trouble with the different comprehension levels of the students?

APPENDIX I: Third Observation Interview Protocol

TA Interview Protocol – Third Round of Observations

General Questions

1. Thank you for taking the time to talk with me and letting me observe your classroom once again. Can you summarize the lab I observed today?
2. How did you prepare for today's class? Was there anything you wanted to specifically go over or wanted the students to work on?

Lab-specific Questions

Lab A

1. Presentation –

Today, you put up two pages of problems from an old Calculus I final. You gave students time to look over it, and then asked which problems they wanted to see worked out. The students suggested problems which you worked on the board or on the overhead. Can you tell why you decided to structure the class this way?

The students really wanted you to post the old final on Facebook, but you were hesitant. Why is that?

Lab B

1. Presentations –

I noticed a lot of uses and discussion of different methods to complete the same problem. Is this something you frequently stress? Or is brought up often in the class or in the lecture?

You also pointed out errors in and lack of notation in the students' work. Can you explain your reasoning?

2. Quizzes –

As the students were taking the quiz, you went around checking their work and stopping by a few of the stronger students. It seems like based on their work, you decided to give them a hint on #2(a). Can you tell me about this?

Lab C

1. Problem Selection –

The beginning of the class was devoted to reviewing derivatives. Can you explain your reasoning for starting the class this way?

After the review, you put up the textbook and instructed the students to work on their homework problems which were circled. You gave them alternate problems to work on if they had completed the homework assignment already. Why did you structure the problems like this?

At the end of class, instead of having the students work on #51 (a HW problem), you worked #57 on the overhead for the students. Can you tell me why you decided to do this?

REFERENCES

Anderson, R.D. & Loftsgaarden, D.O. (1987). A special calculus survey: Preliminary report. In L. A. Steen (Ed.), *Calculus for a New Century: A Pump not a Filter* (pp. 215-216). Mathematical Association of America, *MAA Notes* (8).

Astin, A. W. (1985). Achieving educational excellence: A critical assessment of priorities in higher education. San Francisco: Jossey-Bass.

Astin, A.W., & Astin, H. S. (1992). Undergraduate science education: The impact of different college environments on the educational pipeline in the sciences. Los Angeles, CA: Higher Education Research Institute, UCLA.

Bell, A.W., O'Brien, D., & Shui, C. (1980). Designing teaching in the light of research on understanding. In Karplus, R. (Eds.), *Proceedings of the Fourth International Conference for the Psychology of Mathematics Education*. Berkley, CA: The International Group for the Psychology of Mathematics.

Biesta, G. (2010). Pragmatism and the philosophical foundations of mixed methods research. In Tashakkori, A. & Teddlie, C. (Eds.), *Sage Handbook of Mixed Methods in Social and Behavioral Research* (2nd ed., pp. 95-117). Thousand Oaks, CA: Sage.

Bransford, J.D., Brown, A.L., & Cocking. R.R. (Eds). (2000). *How People Learn: Brain, Mind, Experience, and School* (Expanded edition). Washington, DC: National Academy Press.

Bransford, J., Vye, N., & Bateman, H. (2002). Creating high-quality learning environments:

Guidelines from research on how people learn. In P. A. Gram & N. Stacey (Eds.), The knowledge economy and postsecondary education: Report of a workshop (pp. 159–198). Washington, DC: National Academy Press.

Bressoud, D. M. (1994). Students' attitudes in first-semester calculus. *MAA Focus*, *14*, 6-7.

Bressoud, D. M. (2011a, May). The calculus I instructor. *Launchings.* Retrieved from http://www.maa.org/columns/launchings/launchings_06_11.html

Bressoud, D. M. (2011b, June). The calculus I instructor. *Launchings.* Retrieved from http://www.maa.org/columns/launchings/launchings_06_11.html

Bressoud, D., Carlson, M., Mesa, V., & Rasmussen, C. (2013). The calculus student: Insights from the MAA national study. *International Journal of Mathematical Education in Science and Technology*, *44* (5), 685 – 698.

Business Higher Education Forum (2010). Increasing the number of STEM graduates: Insights from the U.S. STEM education & modeling project. Retrieve from http://www.bhef.com/sites/g/files/g829556/f/report_2010_increasing_the_number_of_stem_grads.pdf

Business Higher Education Forum (2013). The U.S. STEM undergraduate model: Applying system dynamics to help meet President Obama's goals for one million STEM graduates and the U.S. Navy's civilian STEM workforce needs. Retrieved from http://www.bhef.com/sites/g/files/g829556/f/201306/report_2013_stem_undergrad_model.pdf

Chini, J.J. & Al-Rawi, A. (2013). Alignment of TAs' beliefs with practice and student perception. *Proceedings of the Physics Education Research Conference*, *1513*, 98-101. Doi:10.1063/1.4789661

Cho, Y., Kim, M., Svinicki, M.D., & Decker, M.L. (2011). Exploring teaching concerns and characteristics of graduate teaching assistants. *Teaching in Higher Education*, *16*(3), 267-279.

Creswell, J.W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Creswell, J.W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Cox, M.F. (2005). *An examination of the validity of the VaNTH Observation System (VOS)*. (Doctoral Dissertation). Available from ProQuest Dissertations and Theses database (UMI No. 3528086).

Daempfle, P. A. (2002). An analysis of the high attrition rates among first year college science, math and engineering majors. U.S. Dept. of Education, Office of Educational Research and Improvement, Educational Resources Information Center (ERIC).

Davis, M.M., Konopak, B.C., & Keadance, J.E. (1993). An investigation of two chapter 1 teachers' beliefs about reading and instructional practices. *Reading Research and Instruction*, *33*(2), 105-118.

Deacon, C. & Hajek, A. (2011). Student perceptions of the value of physics laboratories. *International Journal of Science Education*, *33*(7), 943-977.

DeChenne, S.E. & Enochs, L. (2010, April). *Measuring the teaching self-efficacy of sciences, technology, engineering, and math graduate teaching assistants*. Paper presented at American Educational Research Conference, Denver, CO.

Fang, Z. (1996). A review of research on teacher beliefs and practices. *Educational Research*, *38*(1), 47-65.

Fausett, L.V. & Knoll, C. (1991). Effective use of teaching assistants in first year calculus. *PRIMUS*, *1*(4), 407-414.

Feder, M. (2012, December 18). One decade, one million more STEM graduates [Blog post]. Retrieved from http://www.whitehouse.gov/blog/2012/12/18/one-decade-one-million-more-stem-graduates

Glesne, C. (2011). Becoming qualitative researchers: An introduction (4th ed.). Boston, MA: Pearson Education, Inc.

Goertzen, R.M., Scherr, R.E., & Elby, A. (2010). Tutorial teaching assistants in the classroom: Similar teaching behaviors are supported by varied beliefs about teaching and learning. *Physical Review Special Topics - Physics Education Research*, *6*(1), 010105-1–010105-17.

Harris, A.H. & Cox, M.F. (2003). Developing an observation system to capture instructional differences in engineering classrooms. *Journal of Engineering Education*, *92*(4), 329-336.

Hilton, T. L., & Lee, V. E. (1988). Student interest and persistence in science: Changes in the educational pipeline in the last decade. *Journal of Higher Education*, *59*(5), 510–526.

Jenkins, J.J. (1978). Four points to remember: A tetrahedral model of memory experiments. In L.S. Cermak & F.I.M. Craik (Eds.), *Levels of Processing and Human Memory*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kendall, D.K. & Schussler, E.E. (2012). Does instructor type matter? Undergraduate student perceptions of graduate teaching assistants and professors. *CBE Life Sciences Education*, *11*(2), 187-199.

Kendall, D.K. & Schussler, E.E. (2013). Evolving impressions: Undergraduate perceptions of graduate teaching assistants and faculty members over a semester. *CBE Life Sciences Education*, *12*(1), 92-105.

Kilgore, K., Ross, D., & Zbikowski, J. (1990). Understanding the teaching perspectives of first-year teachers. *Journal of Teacher Education*, *41*(28), 28-38.

Kyle, W. C. (1997). The imperative to improve undergraduate education in science, mathematics, engineering, and technology. *Journal of Research in Science Teaching*, *34*(6), 547-549.

Lin, S., Henderson, C., Mamudi, W., Singh, C., & Yerushalmi, E. (2013). Teaching assistants' beliefs regarding example solutions in introductory physics. *Physical Review Special Topics - Physics Education Research*, *9*(1), 010120-1–010120-23.

Loftland, J., Snow, D., Anderson, L., & Loftland, L.H. (2006). *Analyzing Social Settings: A Guide to Qualitative Observation and Analysis* (4th ed.). Belmont, CA: Wadsworth.

The Mathematical Association of America. (2004). Undergraduate programs and courses in the mathematical sciences: CUPM curriculum guide 2004. Retrieved from: http://www.maa.org/sites/default/files/pdf/CUPM/cupm2004.pdf

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Fransico, CA: Jossey-Bass.

Moore, L. C. & Smith, D. A. (1987). Toward a lean and lively calculus by Ronald G. Douglas. *The Collegiate Mathematics Journal*, *18*(5), 439-442.

Murphy, L. (2006). Reviewing reformed calculus. Senior Mathematics Project. Retrieved from: http://ramanujan.math.trinity.edu/tumath/research/studpapers/s45.pdf

Muzaka, V. (2009). The niche of graduate teaching assistant (GTAs): Perceptions and challenges. *Teaching in Higher Education*, *41*(1), 1-12.

National Center for Education Statistics. (2009). NCES 2009-161. Students who study Science, Technology, Engineering, and Mathematics (STEM) in postsecondary education. Washington, DC: U.S Department of Education, Institute for Education Sciences. Retrieved from http://nces.ed.gov/pubs2009/2009161.pdf

National Research Council. (1996). *From analysis to action: Undergraduate education in science, mathematics, engineering, and technology: Report of a convocation.* Washington, DC: National Academy Press.

National Science Foundation (1986). Undergraduate science, mathematics and engineering education: Role for the National Science Foundation and recommendations for action by other sectors to strengthen collegiate education and pursue excellence in the next generation of U.S. leadership in science and technology. Washington, DC: National Science Board, NSB Task Committee on Undergraduate Science and Engineering Education.

National Science Foundation. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology.* (A report on its Review of Undergraduate Education by the Advisory Committee to the Directorate for Education and Human Resources, NSF Publication No. 96-139). Arlington, VA.

Newby, W. & Katz, A.N. (1980). Do student ratings of graduate-level laboratory instructors predict how students like lab? *Teaching of Psychology*, 7(2), 87-89.

O'Neal, C., Wright, M., Cook, C., Perorazio, T., & Purkiss, J. (2007). The impact of teaching assistant on student retention in the sciences. *Journal of College Science Teaching*, *36*(5), 24-29.

Onwuegbuzie, A. J. & Combs, J. P. (2010). Emergent data analysis techniques in mixed methods research. In Tashakkori, A. & Teddlie, C. (Eds.), *Sage Handbook of Mixed Methods in Social and Behavioral Research* (2nd ed., pp. 397-430). Thousand Oaks, CA: Sage.

Pajares, M.F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, *62*(3), 307-332.

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oak, CA: Sage.

Prawat, R.S., Remillard, J., Putnam, R.T., & Heaton, R.M. (1992). Teaching mathematics for understanding: Case study of four fifth-grade teachers. *Elementary School Journal*, *93*, 145-152.

President's Council of Advisors on Science and Technology. (2012). Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics [Report to President]. Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_feb.pdf

Scholz, R.W., & Tietje, O. (2002). *Embedded case study methods: Integrating quantitative and qualitative knowledge*. Thousand Oaks, CA: Sage.

Semler, S.W. (1997). Systematic agreement: A theory of organizational alignment. *Human Resource Development Quarterly*, *8*(1), 23-40.

Seymour, E. (2002). Tracking the processes of change in US undergraduate education in science, mathematics, engineering, and technology. *Science Education*, *86*(1), 79-105.

Seymour, E. & Hewitt, N. (1997). Talking about leaving: Why undergraduates leave the sciences. Boulder, CO: Westview Press.

Smith, K.A., Douglas, T.C., & Cox, M.F. (2009). Supportive teaching and learning strategies in STEM education. *New Directions for Teaching and Learning*, *2009*(117), 19-32.

Speer, N. M. (2001). *Connecting beliefs and teaching practices: A study of teaching assistants in reform-oriented calculus courses.* (Doctoral Dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3044694)

Speer, N., Gutmann, T, & Murphy, T.J. (2005). Mathematics teaching assistant preparation and development. *College Teaching*, *53*(2), 75-80.

Springer, L., Stanne, M. E., & Donovan, S.S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Education Research*, *69*(1), 21-51.

Stake, R.E. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Steen, L. (1987). *Calculus for a New Century: A Pump not a Filter*. Mathematical Association of America, *MAA Notes* (8).

Strenta, C., Elliot, R., Russell, A., Matier, M., & Scott, J. (1994). Choosing and leaving science in highly selective institutions. *Research in Higher Education*, *35*(5), 513-537.

Tabaschnick, B. G. & Fidell, L. S. (2007). *Using Multivariate Statistics* (International edition, 5th ed.). USA: Pearson.

Tapping Americas Potential. (2008, July 15). Business leaders call for progress in advancing U.S. innovation by strengthening Science, Technology, Engineering and Math [Press release]. Retrieved from http://tapcoalition.org/news/pdf/tap_progress_press_release.pdf

Taylor, J.A. & Newton, D. (2013). Beyond blended learning: A case study of institutional change at an Australian regional university. *Internet and Higher Education*, *18*, 54-60.

Tinto, V (1993). Leaving college: Rethinking the causes and cures of student attrition. Chicago, IL: University of Chicago Press.

Tobias, S. (1990). They're not dumb: They're different: A new "tier of talent" for science. *Change*, *22*(4), 10-30.

Treisman, U. (1992). Studying students studying calculus: A look at the lives of minority mathematics students in college. *The College Mathematics Journal*, *23*(5), 362-372.

Tucker, A. (2013). The history of the undergraduate program in mathematics in the United States. *American Mathematical Monthly*, *120*(8). Retrieved from: http://www.maa.org/sites/default/files/pdf/CUPM/pdf/MAAUndergradHistory.pdf

Vogt, W. P. (2007). *Quantitative Research Methods for Professionals*. USA: Pearson.

Volkmann, M.J., Abell, S.K., & Zgagacz, M. (2005). The challenges of teaching physics to preservice elementary teachers: Orientations of the professor, teaching assistant, and students, *89*(5), 847-869.

Vye, N.J., Goldman, S.R., Voss, J.F., Hmelo, C., Williams, S., & Cognition and Technology Group at Vanderbilt. (1997). Complex mathematical problem solving by individuals and dyads. *Cognition and Instruction*, *15*(4), 435-484.

Vye, N.J., Schwartz, D.L., Bransford, J.D., Barron, B.J., Zech, L., and Cognition and Technology Group at Vanderbilt. (1998). SMART environments that support monitoring, reflection, and revision. In Hacker, D., Dunlosky, J., & Graesser, A. (Eds.), *Metacognition in Educational Theory and Practice* (pp. 305-347). Mahwah, NJ: Erlbaum.

Vygotsky, L.S. (1978). *Mind in Society: The Development of Higher Psychological Processes.* Cambridge, MA: Harvard University Press.

Wiggins, G. & McTighe, J. (1997). *Understanding by Design.* Alexandria, VA: Association for Supervision and Curriculum Development.

Yin, R.K. (2009). Case study research: Design and methods (4th ed.). Thousand Oaks, CA: Sage.

Young, C. Y. , Georgiopoulos, M. , Hagen, S. C. , Geiger, C. L. , Dagley-Falls, M. A. , Islas, A. L. , … Bradbury, E. E. (2011). Improving student learning in calculus through applications. *International Journal of Mathematical Education in Science and Technology*, *42*, 591-604. doi: 10.1080/0020739X.2010.550944