5-1-2022

Teaching Beliefs and Teaching Practices: A Sequential Mixed Methods Study of Post-Secondary Mathematics Faculty

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TEACHING BELIEFS AND TEACHING PRACTICES: A SEQUENTIAL MIXED METHODS STUDY OF POST-SECONDARY MATHEMATICS FACULTY

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A dissertation submitted in partial fulfillment
of the requirements for the

Doctor of Philosophy – Curriculum & Instruction

Department of Teaching & Learning
College of Education
The Graduate College

University of Nevada, Las Vegas
May 2022

UNLV | GRADUATE COLLEGE

Dissertation Approval

The Graduate College
The University of Nevada, Las Vegas

April 8, 2022

This dissertation prepared by

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entitled

Teaching Beliefs and Teaching Practices: A Sequential Mixed Methods Study of Post-Secondary Mathematics Faculty

is approved in partial fulfillment of the requirements for the degree of

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Abstract

This mixed methods study explored the relationship between collegiate math instructors' reported teaching practices, teaching beliefs, and actual teaching practices. Instructors reported their own teaching practices by survey. Qualitative participants were purposively sampled from the quantitative survey results. These qualitative participants presented their teaching beliefs through an initial interview. Afterward, actual teaching practices were confirmed through classroom observations. Lastly, instructors completed reflective interviews to address findings in the previously collected data.

Through the survey instrument, this study established common teaching practices of collegiate math instructors. The study identified that on average the post-secondary math instructors in this sample employed between 26 to 27 research-based teaching practices in their classrooms. Several of these research-based practices relate to feedback and testing for students and student assignments.

Next, through the application of multiple measures of data collection, this study constructed a rich description of the teaching beliefs and teaching practices for seven qualitative participants. This study established that instructors were mostly consistent between their self-reported practices, teaching beliefs, and observed teaching practices. Furthermore, when an inconsistency did occur the discrepancy was most often contributed to external factors rather than a direct contradiction between the instructor's espoused beliefs and preferred theories-in-use.

The study identified two main factors that should be considered when promoting faculty adoption of student-centered teaching practices. First, contentment with current teaching practices impacted instructor willingness to attempt new methods. Second, an instructor's held

anxiety that implementing new teaching practices may lead to ineffective instruction or poor results.

Acknowledgements

It is with a feeling of great relief and pride that I write this short piece of acknowledgement to and for those who have guided, supported, and encouraged me throughout the journey toward obtaining my Ph.D.

First and foremost, to Dr. Micah Stohlmann, my dissertation advisor, for your support and belief in this work from day one. Each and every meeting with you brought not only insight but also reassurance in the purpose of this research. Your unyielding belief in my ability to succeed, and your ability to calm my nerves while being so impressively efficient, consistent, and reliable has made you not only my advisor but a true confidant. For your willingness to go above and beyond, I truly thank you.

To Dr. Jeffrey Shih and Dr. Travis Olson, thank you for accepting a place on my committee. Both of you have been invaluable to the formulation of this study in providing professional advice regarding my proposal and consistent recommendations throughout my work. I could always rely on you for varied perspectives, relevant input, and purposeful feedback. Thank you.

To Dr. Doug Burke, not only were you my Masters' Thesis advisor but now as my graduate college representative and a member of this committee, you have once again proven your relentless and dedicated investment in my academic success. Over the last nine years, I have counted on you as a constant source of inspiration and support.

In any meaningful and substantial undertaking, no person is an island– it truly does take a village for any individual to succeed. Because of this, I wish to thank my many loyal and encouraging friends who have seen me through this endeavor with love and aplomb. Rebecca Davis, for your many hours of emotional and grammatical support; you make me better. My

appreciation for your intellect, friendship, and selflessness is unending. Jonah Shulman and Averill Kelley, you both were new friends when I started this process, and through the years have become invaluable spirits in my life. Jonah, you and I have pushed each other to not only succeed but to do so on time. This is proof of your support. Averill, my sounding board and motivational coach. Your constant reassurance has undoubtedly led me here. Kelley DeLoach, my rock, my constant, my North Star. There is no length to which you would not go to support me in every success in life, including this one. Your acts of kindness have provided me calm and solace when I needed it most; thank you will never be enough.

And, to my family. My brothers, Kade and Kyle, we are more than family, more than friends. Your love, support, words of encouragement, tight hugs, meaningful visits, and fits of laughter have so often lifted me out of moments where fear and frustration threatened to render me immobile. In you I have an eternal foundation in life. In you I find the strength to go on.

Finally, to my father. I will say it again, you are my oldest friend and constant resource of renewable love and energy. In this chapter of my life, you have once again proven to me in an ever more profound and exponential way that our connection goes beyond father and daughter. Our unwavering devotion to one another has made us both more resilient and resolute human beings. To know that I always have you in my life has made me fearless. Because of you, I know I can do anything. And now, I have.

The only person who ever doubted that this degree would come to fruition was me. To my advisor, committee members, friends, family, and countless others unnamed here but forever in my heart, you have been the power and confidence that I have relied on throughout my journey to this achievement. Whether you knew it or not, every single day I felt your outpouring of love. We made it!

– Katlyn K. Cox

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Chapter 1

Introduction

Improvements for undergraduate education have been a repeated request for several years (Addy et al., 2015; Beach et al. 2012; Gandhi-Lee et al., 2015; Hora & Ferrare, 2013; Moore et al., 2015; National Research Council, 2013; Wieman & Gilbert, 2014). In 2012, the President's Council of Advisors on Science and Technology projected that approximately one million more STEM professionals would be needed by 2022; to meet these demands the United States would need to produce 34% more STEM degree graduates each year (Gandhi-Lee et al., 2015; PCAST, 2012). Mathematics content has been identified as a major hurdle to overcome in order to be successful in STEM fields (Gandhi-Lee et al., 2015). Although a prioritization for education improvements in STEM fields has been documented (Gandhi-Lee et al., 2015), policymakers and educators continue to express concerns that math and science fields are not creating meaningful educational experiences for students (Hora & Ferrare 2013; PCAST, 2012).

Advancing pedagogical practices has been acknowledged as a high priority in K-12 education (NCTM, 2014; NRC, 2000). Unfortunately, despite research that emphasizes the importance of teaching methods in elementary and secondary education, training for post-secondary STEM faculty in pedagogy and learning theories is limited (Brown et al., 2006; Gandhi-Lee et al., 2015; Speer & Hald, 2008). Moore et al., (2015) note some of the vital parts of effective pedagogy, "Successful teaching includes designing effective courses that involve innovative lessons, using appropriate teaching strategies, and developing robust techniques to assess student learning" (p. 281).

Improvements should be researched and implemented to create better pedagogical understanding and practices for tertiary faculty. Hora (2016) stated that "a growing area of

interest… is whether faculty are adopting research-based teaching techniques, such as problem-based learning or peer instruction, and if not, why not?" (p. 1). One method for answering this question is to first understand what teaching practices are currently being used in college classrooms. Furthermore, teaching practices are impacted by teaching beliefs (Addy et al, 2015; Ernest 1994; Holland, 2018; Pajares, 1992; Philipp, 2007). Due to the interconnectedness of teaching practices and teaching beliefs, it is important to study teaching beliefs to answer the "why" or "why not" in the questions presented by Hora (2016) above.

Research Purpose/Significance

If we wish to understand teachers' practices, it is crucial that we understand teachers' beliefs (Luft & Roehrig, 2007). Evaluation of undergraduate mathematics faculty beliefs about pedagogy is important for improving teaching practices at the postsecondary level. Faculty members are pivotal in educational reforms (Moore et al. 2015). It has been noted that college STEM faculty have very little training in teaching practices (Gandhi-Lee et al., 2015). Therefore, it is essential that we have a basis of knowledge to evaluate mathematics faculty in their current perception of pedagogy so that future changes can be implemented to improve undergraduate education in mathematics courses. A critical research problem is understanding why faculty choose to apply their current practices and fail to use more modern research-based teaching pedagogy (Oleson & Hora, 2013). Additionally, Hora and Anderson (2012) claim "one of the core problems facing pedagogical reform is to identify the factors that lead faculty to adopt interactive teaching methods" (p.586).

Mesa and Griffiths (2012) specifically reference calls for improving instruction in "undergraduate mathematics to promote greater student engagement" (p. 85). In a later work by Mesa and colleagues (2014), the authors describe that connecting higher education and

mathematics education to studying instruction "can shed light on the relationship between how instructors describe their practice and how they enact such practices in their mathematics classrooms" (p. 120). Moreover, Luft and Roehrig (2007) justify the study of teacher beliefs: "capturing the beliefs of teachers is important… ultimately, beliefs reveal how teachers view knowledge and learning, and suggest how they may enact their classroom practice" (p. 47).

Research on undergraduate faculty demonstrates that many post-secondary faculty are lacking in pedagogical knowledge, as well as lacking in pedagogical content knowledge prior to starting as instructors (Ellis, 2014; Kane et al. 2002; Reys et al, 2009; Speer & Hald, 2008; Yow et al., 2016). One method for supporting these faculty could be through providing pedagogical knowledge and mentoring support (Ellis, 2014; Reys et al, 2009; Speer & Hald, 2008; Yow et al., 2016). Furthermore, it is important that researchers understand the teaching beliefs of these instructors, so teaching practices and teaching beliefs may be integrated (Ernest, 1994) and, thus, are more likely to be implemented in the classroom (Philipp, 2007). Better understanding the interactions between teaching practices and teaching beliefs of undergraduate mathematics faculty provides important information to ensure meaningful and successful experiences are provided for students (Hora & Ferrare, 2013).

This mixed-methods study plans to investigate current teaching practices used by undergraduate mathematics instructors and the teaching beliefs of those instructors. The study further wishes to determine common teaching practices of undergraduate mathematics faculty, their common teaching beliefs, and explore relationships between enacted teaching practices and teaching beliefs. An explanatory sequential mixed methods design with a case selection and case study variant will be performed (Creswell & Plano Clark, 2018). First, quantitative data will be collected to inform the case selection of participants for the qualitative data collection that

follows. By using the quantitative data to create groups of instructors that indicate varied levels of research-based teaching practices, the researchers will be able to identify common teaching beliefs that are associated with particular teaching practices. Furthermore, the quantitative data and qualitative data will be analyzed together to form a well-rounded perspective of the relationship between teaching beliefs and teaching practices. The use of an explanatory sequential design will give this study more depth by creating thick qualitative descriptions of the processes and teaching beliefs associated with teaching practices. Although current research has attempted to make these connections, the researcher believes that integrating quantitative and qualitative findings will broaden and bridge our understanding of the relationship between teaching practices and teaching beliefs in a manner that has not been previously accomplished by separate quantitative and qualitative studies.

Kane et al. (2002) emphasize the importance of understanding both teaching practices and teaching beliefs, "we argue that an understanding of university teaching is incomplete without a consideration of teachers' beliefs about teaching and a systematic examination of the relationship between those beliefs and teachers' practices" (p. 180). Many of the studies discussed in the literature review in the next section identify limitations in research due to self-reported data (Kane et al. 2002; Speer 2005). Therefore, this research study will leverage multiple measures so data collection will not be restricted to self-reported data. Furthermore, this study will incorporate reflective interview practices to establish shared understanding between the researcher and research participants (Li, 2013; Speer, 2005). This interview technique has an added advantage of giving the researcher the opportunity to discuss discrepancies between espoused beliefs and enacted practices with the research participants. This will provide more interpretation to the findings and give the faculty members further opportunity to reflect on their

teaching practice. There is one research question for this study that investigates the relationship between teaching practices and teaching beliefs for instructors of undergraduate mathematics courses.

Research Question

1. What is the relationship between reported teaching practices, teaching beliefs, and actual teaching practices for collegiate math instructors?

Chapter 2

Literature Review

This literature review begins by describing common university teaching practices, explaining some of the expansive terminology that is often employed in describing teaching practices, and presenting examples of recent research surrounding university teaching practices within STEM education. Following that is a discussion about teaching beliefs. This portion of the review begins with an explanation of beliefs features, then discusses the importance of teaching beliefs, and illustrates research about the connection between teaching beliefs and teaching practices. The subsequent section features recent research studies in non-STEM fields that investigate relationships between teaching beliefs and teaching practices at the tertiary level. A brief analysis on the appropriateness of self-reporting to capture teaching practices follows. Lastly, the final section reviews the theoretical framework that will be employed in this research study.

Studies on Teaching Practices within STEM Education

Since STEM disciplines are highly connected, looking at beliefs studies that have been completed with faculty in other STEM disciplines can provide insights for methods exploring beliefs, possibilities for supporting productive teaching beliefs, and information on the complexities of teaching STEM content at the college level, therefore informing research on beliefs for mathematics faculty. Many of the studies discussed below focus on STEM faculty as a group. Any findings that are specific to mathematics faculty are noted.

For the most part, teaching in college mathematics classrooms uses a knowledge transmission model: a method of teaching which is teacher-centered where content focused information is provided to students without an opportunity to practice it (Bailey et al., 2015;

Edwards et al. 2015; Grubb, 1999; Grubb & Gabriner, 2013; Hora, 2016; Hora & Ferrare, 2013; Kember & Gow, 1994). Although lecture based classes seem prominent in STEM fields, Oleson and Hora (2013) attempted to gather evidence to show that this may not always be the case.

Their research consisted of interviews for 53 undergraduate STEM faculty members (15 were math faculty). Many of the interview respondents explained that as teachers, they want to engage their students (Oleson & Hora, 2013). The researchers conducted classroom observations of some of the participants for more in-depth analysis. After observations and interviews, Oleson and Hora (2013) summarized their evaluation of one of the faculty members stating, "regardless of [his] goals, lecturing was still the dominant mode of instruction, which suggests that more tacit views of teaching and/or habituated practices may guide [his] teaching more than his self-reported decision-making steps articulated in the interview" (p. 39).

In a second example that Oleson and Hora (2013) described, the instructor discussed her preference for giving students the opportunity to work problems at the board during class. She further preferred to work problems in class instead of just talking about the theory. Oleson and Hora (2013) summarize "the intention of the structured discussion approach to surface student misconceptions through board work was observed" (p. 40). In this case, the instructor was able to make her class more student-centered, yet the use of lecture (a teacher-centered approach) was still present (Oleson & Hora, 2013).

Teaching approaches described by research generally fall into one of two categories: teacher-centered or student-centered. Many researchers advocate a more student-centered approach (Addy et al., 2015; Luft & Roehrig, 2007; Mesa et al., 2014; Moore et al., 2015). Yet, Mesa and associates (2014) explain that the influence of student-centered learning in higher education merits further investigation. Mesa et al. (2014) explain that teachers are crucial in the

classroom regardless of their mode of instruction, so all instruction is teacher-centered. Instead, Mesa et al. (2014) define student-centered approaches and content-centered approaches:

> We call *student-centered* approaches those instructor descriptions and strategies that appear to be driven by the instructors' interest in attending to students' cognitive, social, and emotional needs, seeking to give students a more prominent role in classroom activities. We call *content-centered* approaches those instructor descriptions and strategies driven by instructors' interest in emphasizing the content over students' cognitive, social, or emotional needs and involvement (p. 122-123).

In their research, Mesa et al. (2014) interviewed and observed 14 mathematics instructors at a large suburban community college. The researchers used both the definitions of student-centered and content-centered above, as well as Grubb's (1999) three teaching approaches.

Grubb (1999) describes teaching approaches as being traditional, meaning-making, or student-support style. In a traditional style of teaching, the teacher is the main source of knowledge and explanation (Grubb, 1999). The traditional teaching approach aligns with the "teacher-centered" approach. Grubb (1999) explains that the meaning-making approach has a central goal: for the students to create meaning for themselves. Grubb (1999) continues his explanation saying that the meaning-making style has also been described as "progressive," "constructivist," or "student-centered." Lastly, the student-support approach is a style in which the instructor shows concern for their students and places particular emphasis on caring that the students understand (Grubb, 1999). Thus, the student-support approach seems to be student-centered.

In their interviews, Mesa and colleagues (2014) found that the traditional approach (Grubb, 1999) was described the most often (11 of 14 instructors), but many of the instructors described more than one teaching approach. Mesa et al. (2014) describe, "what matters most to

these instructors is that the students receive all the content that needs to be covered, even if their students cannot keep up with the pace of the lecture" (p. 134). They found that six of the instructors also used meaning-making approaches (Grubb, 1999) and seven of the instructors used student-support approaches (Grubb, 1999; Mesa et al., 2014).

In Martin et al.'s (2000) evaluation of how university faculty teach, the authors argue three main ideas. First, different teachers have distinct intentions for what students will learn, so it follows that they construct the content or topics to be taught in different ways, even if it is the same course with identical exams (Martin et al., 2000). Second, teachers' goals for the content that students should learn is highly related to the teachers' expectations of how students learn and how they may be helped through teaching. (Martin et al., 2000). Third, when teachers are focused on a certain topic, their teaching practices and their objectives for teaching are closely associated (Martin et al, 2000).

Wieman and Gilbert (2014) recognized that information regarding teaching practices of STEM faculty at the tertiary level was limited. To remedy this issue, Wieman and Gilbert (2014) developed the Teaching Practices Inventory (TPI). There are eight categories for the TPI: course information, supporting materials provided to the students, in-class activities, assignments, feedback and testing, training and guidance, collaboration, and other. A rubric/scoring system was developed for the TPI which assigns points to teaching practices that are related to research-based practices that improve learning (Wieman & Gilbert, 2014). Moreover, the TPI contains a 72-item list of teaching practices which were commonly or occasionally used in math or science courses. The survey was updated in 2018 to included two more research-based teaching practices, increasing the list of practices to 74 (Carl Wieman Science Education Initiative, 2018).

Wieman and Gilbert (2014) explain that the TPI was developed with the aim that the science and mathematics faculty who completed the survey would understand the items, "in a

consistent and accurate manner and that the inventory covered all teaching practices used by more than two instructors in our large, [150 person], test sample" (p.553). The inventory went through multiple iterations. These changes were informed by the test sample and informal discussions with instructors from mathematics and science departments as well as a systematic review of observed teaching practices (Wieman & Gilbert, 2014). Furthermore, the researchers utilized multiple avenues of comparison between TPI results to confirm accuracy in responses to the TPI. These processes included comparing results between instructors who shared teaching responsibilities in team taught courses, using classroom observations to compare observation results to TPI results, and having randomly selected TPI results compared to a TPI survey completed by an educational specialist within the instructor's department who was familiar with the instructors' teaching practices and their courses (Wieman & Gilbert, 2014).

Not only does the Teaching Practices Inventory act as a survey instrument, but it also establishes an extensive list of teaching practices used by STEM faculty. Some of the teaching practices on the TPI include: pausing to ask students questions during class, having small group discussions in class, having discussions during the term with the intention of explaining why the topic is of interest to students, having students complete reflective activities at the end of class, providing students with a list of topics to be covered, and identifying the percent of time that the instructor spends lecturing during each class i.e. teaching content, deriving mathematical results, and working through problems at the board (Wieman & Gilbert, 2014). Additionally, Wieman and Gilbert (2014) identified 51 specific research-based teaching practices that appear on the inventory, examples include: students' presentations, papers, or projects, encouraging students to meet individually with the instructor, providing lecture notes, providing in-class activities for students to engage them, and providing solutions to homework assignments. In the most updated version of the TPI, two more research-based teaching practices were added so there are now 53

specific research-based teaching practices on the survey (Carl Wieman Science Education Initiative, 2018).

In 2019, Alsharif and Alamri conducted a study using the Teaching Practice Inventory (Wieman & Gilbert, 2014) to survey 78 undergraduate mathematics faculty at King Saud University. Alsharif and Alamri (2019) found that the math instructors in their sample scored the highest in collaboration and in-class activities while scoring the lowest in the diagnostic practices such as pre/post testing students and in providing feedback for exams, e.g. providing students with an answer key or rubric explaining grading for exams. Low scores on the TPI in these categories indicate that the instructors were not using many research-based teaching practices for diagnostics measures and exam feedback for their students. On the other hand, high scores indicated this group of instructors frequently use research-based teaching practices for collaboration with colleagues and for in-class activities such as student presentations. The researchers also compared instructor scores using courses that each instructor taught to determine which courses were taught most effectively based on the scores from the TPI rubric. According to this system of scoring, the most effectively taught courses by the participants were Introductory Mathematics and Precalculus courses. In contrast, the least effectively taught courses were Integral Calculus and Numerical Methods (Alsharif & Alamri, 2019).

In a mixed methods study completed by Hora and Anderson (2012) the researchers explored the relationship between decision making and teaching practices for STEM faculty at institutions of higher education. Through the use of survey data and interviews the researchers gained insight for the choices made by faculty. Hora and Anderson (2012) explain,

> In addition, one of the unique characteristics of math faculty in the study was that several were teaching courses that had multiple sections and thus had a fixed curriculum where

> several classes shared a syllabus, textbooks, lecture notes, and assessments, thereby imposing a structured set of expectations on the instructors teaching the same course (p. 585).

This study revealed that different types of norms operate within post-secondary institutions and within the separate socio-cultures of those institutions (Hora & Anderson, 2012). Furthermore, teaching norms impact faculty and their practices as three distinct levels: the institution, the subject discipline, and the department in which they teach (Hora & Anderson, 2012). This study establishes another dynamic for which faculty integrate beliefs, external expectations, and teaching practices.

Teaching Beliefs

It is difficult to express a precise definition of teaching beliefs. Beliefs have been described differently depending on the research context (Luft & Roehrig, 2007). Many researchers have expressed the complexity of beliefs (Nespor, 1987; Pajares, 1992). Moore et al. (2015) interpret teaching beliefs as "personal constructs that are important to an educator's teaching practices" (p. 281), which is the perspective this research will utilize. However, for the purpose of this study it is essential that some of the intricacies of beliefs are discussed. Thus, the remainder of this section clarifies key features of beliefs.

A fundamental concept for this research is that "beliefs" are different from "knowledge." Nespor (1987) developed a "theoretically-grounded model of 'beliefs systems'" (p. 317) in which four features were identified that separate beliefs from knowledge; Nespor further described two other features for characterizing beliefs systems.

There is an *existential presumption:* "beliefs systems frequently contain propositions or assumptions about the existence or nonexistence of entities" (Nespor, 1987, p. 318). Nespor (1987) gives an example of this by stating that the two math teachers in the study both held beliefs about "ability," "maturity," and "laziness." These terms were "labels for entities thought to be embodied by the students" (Nespor, 1987, p. 318).

There is *alternativity:* this "refers to the conceptualizations of ideal situations differing significantly from present realties" (Nespor, 1987, p. 319). An example of this is when a teacher visualizes an ideal classroom and attempts to emulate it even though they never experienced that classroom, nor was the classroom based on a known model. It was simply what they believed to be desirable (Nespor, 1987).

There are *affective and evaluative aspects:* these include "feelings, moods, and subjective evaluations based on personal preferences" (Nespor, 1987, p. 319). Teacher expectations or personal evaluations of what content is important to teach are examples of affective and evaluative aspects. Nespor (1987) explains, "affect and evaluation can thus be important regulators of the amount of energy teachers will put into activities and how they will expend energy on an activity" (p. 320).

There is *episodic storage:* "belief systems are composed mainly of 'episodically' stored material derived from personal experience or from cultural or institutional sources of knowledge transmission (e.g. folklore)" (Nespor, 1987, p. 320). This exemplifies the notion that instead of storing ideas in associative networks, like knowledge, one stores beliefs based on personal experiences or events. Additionally, "beliefs often derive their subjective power, authority, and legitimacy from particular episodes or events" (Nespor,

1987, p. 320). In Nespor's (1987) study, many of the teachers drew upon memories of integral experiences to shape their teaching practices.

The next feature is a characteristic of belief systems instead of individual beliefs. It is a consequence of the features above. *Non-consensuality* "refers to the fact that belief systems consist of propositions, concepts, arguments, or whatever that are recognized- by those who hold them or by outsiders- as being in dispute or as in principle disputable" (Nespor, 1987, p.321). Moreover, this relates to the idea that beliefs are somewhat static in nature, difficult to change, and are typically not open to significant examination by an outside observer (Nespor, 1987).

The other characteristic of belief systems that Nespor (1987) describes is unboundedness. *Unboundedness* describes the characteristic "that people read belief-based meanings into situations where others would not see their relevance" (Nespor, 1987, p.321). People have the ability to tie their beliefs to many different phenomena, sometimes in extreme or unpredictable ways (Nespor, 1987).

Ultimately, teaching beliefs are complex, varied, and entangled. According to Pajares (1992):

> The construct of educational beliefs is itself broad and encompassing… as with more general beliefs, *educational beliefs about* are required- beliefs about confidence to affect student's performance (teacher efficacy), about the nature of knowledge (epistemological beliefs), about causes of teachers' or students' performance (attributions, locus of control, motivation, writing apprehension, math anxiety), about perceptions of self and feelings of self-worth (self-concept,

> self-esteem), about confidence to perform specific tasks (self-efficacy). There are also educational beliefs about specific subjects or disciplines (p. 316).

There are several types of beliefs around teaching and in many different areas, even when focusing on a specific subject. It is critical to note that beliefs are distinct from knowledge (Nespor, 1987). The next section concentrates on teaching beliefs with respect to teaching practices.

Teaching Beliefs and Their Relationship to Practices in STEM Education

Acceptance of pedagogy is tied to rooted beliefs about how learning works (Addy et al, 2015; Holland, 2018). Gandhi-Lee et al. (2015) explain that, "teaching strategies employed in a classroom, then, result from a negotiation between an instructors' idealized beliefs about teaching and learning and their perceptions of their students' abilities and other context-based factors" (p.33). In order to make changes to pedagogical practices, it is important that the research community understand teacher beliefs, especially at the tertiary level, where research of undergraduate mathematics belief is limited (Brown et al., 2006; Gandhi-Lee et al., 2015; Speer & Hald, 2008). According to Pajares (1992), "learning and inquiry are dependent on prior beliefs that not only make current phenomena intelligible but also organize and define new information" (p. 320).

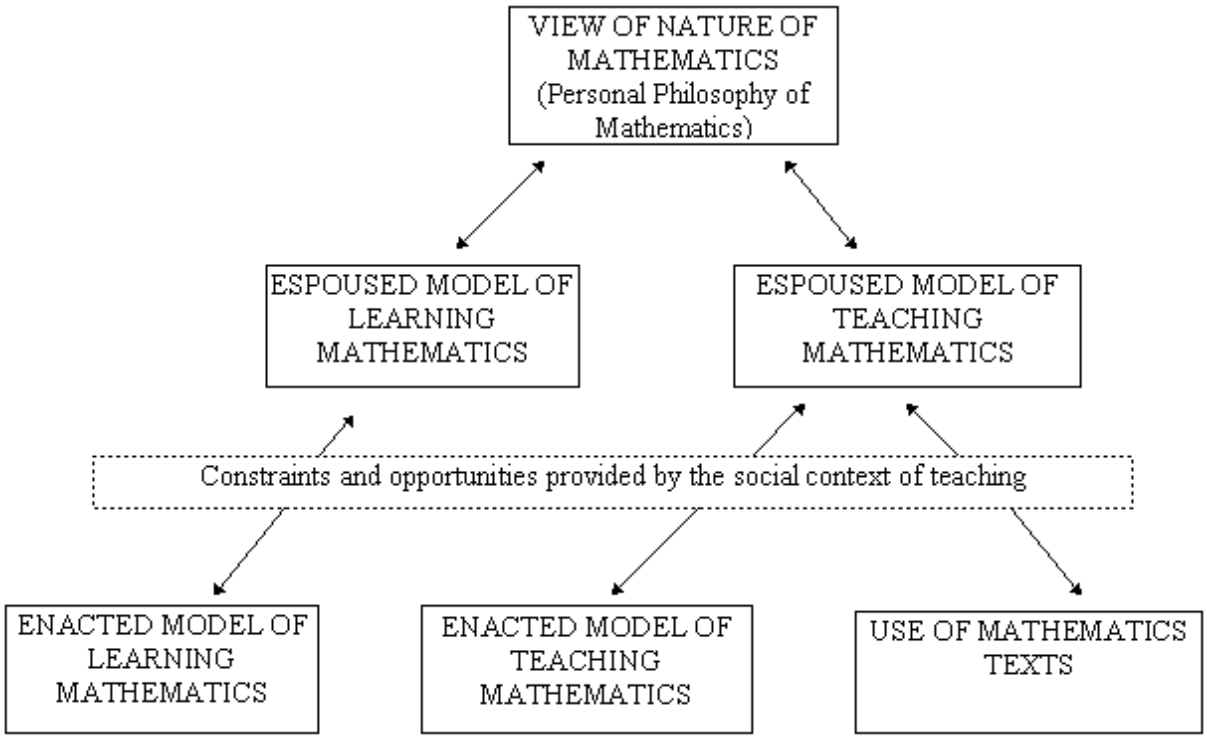
Teacher beliefs are critical for understanding teaching styles and inducing changes in pedagogy (Kensington-Miller et al., 2012; Nespor, 1987; Pajares, 1992). Beach et al. (2012) articulate the relevance of understanding teacher beliefs "by shifting these [STEM] courses from an instruction- or teacher-centered to a learning- or students-centered paradigm, faculty can address high attrition rates, model best teaching practices (for all levels), and establish

educational practice as a scholarly and culturally valued pursuit within STEM disciplines" (p.53).

There is a relationship between teaching practices and teaching beliefs (Ernest 1994; Philipp, 2007). Although, it is unclear whether a change in beliefs allows a change in teaching practice (Pajares, 1992) or a change in teaching practices influences a change in beliefs (Thompson, 1992), there is agreement that the two ideas are highly connected (Philipp, 2007; Ernest, 1994). Ernest (1994) argued "that mathematics teachers' beliefs have a powerful impact on the practice of teaching" (p.5). Ernest (1994) created a diagram (see Figure 1 below) to illustrate the relationship between teaching practice and espoused beliefs. It is important to note that all arrows in the diagram are two directional. The use of mathematics texts can be expanded to include teaching resources including technology integrated in the teaching and learning of mathematics. Teachers' beliefs on learning, teaching, and assessment are important to determine to understand teachers' practices (Luft & Roehrig, 2007).

Figure 1

Relationships Between Beliefs and Their Impact on Practice



Note. Adapted from "The Impact of Beliefs on the Teaching of Mathematics," by P. Ernest, 1994. In A. Bloomfield & T. Harries (Eds.), *Teaching and Learning Mathematics,* Derby: Association of Teachers of Mathematics. (http://socialsciences.exeter.ac.uk/education/research/centres/stem/publications/pmej/impact.htm)

The dynamic relationship between teaching beliefs and teaching practices indicates the importance of understanding instructor beliefs. Nespor (1987) expresses that if,

> … we are interested in why teachers organize and run classrooms as they do we must pay much more attention to the goals they pursue (which may be multiple, conflicting, and

not at all related to optimizing student learning) and to their subjective interpretations of classroom processes (p. 325).

Speer (2005; 2008) argued that some of the inconclusive research connecting teaching beliefs and teaching practices may be due to the research methods used. Speer's (2008) research showed that through looking at case specific research with fine-grained levels of detail, previously ambiguous connections between beliefs and practices could be explained. After analysis of a single case for one collegiate math instructor, Speer (2008) identified that the teacher was consistent in using his beliefs to justify his decisions. Additionally, the rationale for his decisions was never based upon a single belief. Instead justification for teaching decisions were made using collections of beliefs. Speer (2008) defines a collection of beliefs as "a small set of related beliefs that, in combination, describe a teacher's perspective on a particular topic" (p. 235). A collection of beliefs can contain one or more beliefs and may include a variety of constructs related to education such as learning practices, mathematics content or subject knowledge, teaching practices, or student behaviors (Speer, 2008). Therefore, Speer (2008) promotes carrying out research on a smaller and detailed scale to advance knowledge of relationships between beliefs and practices.

Recent research at the tertiary level has provided evidence that instructor beliefs are important in order to understand what happens in their classrooms (Kensington-Miller et al., 2012, Oleson & Hora, 2013). Furthermore, changes in classroom practice such as teaching using Model-Eliciting Activities and increased pedagogical knowledge can influence instructor beliefs, leading to more research-based teaching practices being enacted in college classrooms (Addy et al., 2015; Kensington-Miller et al., 2012; Moore et al., 2015; Oleson & Hora, 2013).

Non-STEM Findings on Teaching Beliefs Relationships to Teaching Practices

Research in teaching beliefs in nonspecific discipline areas is widespread. In 1997, Kember reviewed 13 papers on beliefs of tertiary instructors focused on conceptions of teaching. After synthesis, Kember (1997) concluded that instructors' beliefs could be categorized on a continuum of "teacher-centered/content-oriented and student-centered/learning oriented" conceptualizations (p. 273). However, this research focused only on conceptualizations of teaching without any explorations of teaching practices that were actually enacted. Samuelowicz and Bain (2001) also discussed "belief orientations" of university faculty. They specifically focused on beliefs through an interview process without connection to teaching practices conducted by the research participants. These belief orientations similarly described teaching-centered to learning-centered conceptions (Samuelowicz & Bain, 2001). Additionally, Samuelowicz and Bain (2001) state "because efforts to improve teaching are predicated on the assumed link between teaching and learning, this relationship has to be investigated further even though the available evidence is encouraging" (p.323).

Norton et al. (2005) explored relationships between beliefs and teaching intentions through the use of a questionnaire with a sample of 638 instructors from four universities in the United Kingdom. Based on their analysis, the researchers claimed that "teachers' intentions are more oriented towards knowledge transmission than their beliefs, but at the same time they are not less orientated towards learning facilitation" (Norton et al., 2005, p. 551). Portions of this research supported consistency between teaching beliefs and intentions for learning facilitation while other portions of their analysis showed inconsistency between beliefs and intentions for problem solving, knowledge of the subject, and interactive teaching (Norton et al., 2005). Norton

et al. (2005) concluded that "teachers' intentions represent a compromise between their conceptions of teaching and their academic and social context" (p. 564).

More recently, in 2017, Nghia interviewed 41 Vietnamese university instructors in regard to teaching beliefs and teaching behaviors. Nghia's (2017) research reinforced the indirect relationship between instructor's beliefs and behaviors. The study focused on the instruction of generic skills: "non-discipline specific skills that can be found across disciplines and are transferable between study, work, and personal life contexts" (Nghia, 2017, p. 106). Analysis of the interview data showed that a main factor in transitioning teaching beliefs to teaching practices was the leadership of the institution-- favorable policies towards teaching general skills to students encouraged instructors to actively use their beliefs about teaching general practices to their students (Nghia, 2017). Other factors cited that discouraged adoption of practices were related to management. These included lack of staff development, time constraints in teaching, and teaching workloads (Nghia, 2017). Personal motivators such as industrial experience, goals for improving teaching skills, and motivations to help students learn more effectively impacted the translation of teaching beliefs into teaching practices (Nghia, 2017).

In these studies researchers explored teaching beliefs, intentions, and conceptions for instructors at institutions of higher education. Although beliefs were explored, many of the research studies simply made inferred connections about teaching beliefs relationship to teaching practices. Researchers recognized the need for additional research exploring further development of instruments (Norton et al., 2005), examining more specific areas instead of generalization for all university faculty (Assen, 2016), and in investigating occurrences of beliefs in teaching practice (Kember, 1997; Li, 2013; Nghia, 2017; Samuelowicz & Bain, 2001). Li (2013) stated, "analysis suggests that teachers' beliefs should not be treated as the private realm of the mind

and confirms that the relationship between beliefs and classroom practices is far more complex" (p. 189).

Some researchers have attempted to connect teachers' beliefs and teaching practices. In 2013, Li investigated a single case study with the specific goal of investigating the relationship between teaching beliefs and practice. Li (2013) explored teaching beliefs through the use of semi-structured interviews, teaching practices through video recordings and transcripts of classroom interactions, and the participant's own interpretations of the relationship between their beliefs and practices by reviewing clips of their own class and commenting on what was happening in the recording. The main findings of this study were that a strict one-to-one relationship between beliefs and practices did not exist, that the teacher's theories are dependent upon the context of the environment, and that more analysis is important to understand these complex relationships (Li, 2013).

Assen (2016) conducted a mixed-methods study examining teacher beliefs and teacher interventions under a problem-based learning context. In this problem-based learning context the teacher takes on the role of being a "tutor." The tutor perspective represents shifting to a role of facilitation instead of direct instruction as a teacher would. In this case, the research participants were teachers at a Dutch university within the hospitality management program acting as "tutors" in the problem-based learning environment. The study results demonstrated a large discrepancy: the teachers' interventions showed a more direct teaching style while their espoused beliefs indicated a self-directed and collaborative teaching style (Assen, 2016). Additionally, results showed that several factors hampered learner-oriented teaching behaviors (Assen, 2016). Assen (2016) concluded that changes in beliefs did not seem to automatically create changes in behavior and teachers have difficulty in using supportive style methods to guide the process of

learning versus supporting content. Assen (2016) explains further, “the way the curriculum is designed as well as the tutors' confidence in students' capabilities and confidence in their own facilitation skills explain tutor interventions better than the beliefs about teaching and learning” (p. 21). Assen (2016) recommended more observation studies in different programs and more research to build further understanding of the way that teachers change their beliefs and their behavior.

In summary, the complex relationship between beliefs and practice of college faculty requires further research. Research has suggested that teachers make compromises between their beliefs and enacted teaching based on different influences (Norton et al., 2005). This can include lack of support or knowledge for student-centered learning, time constraints, and workload (Nghia, 2017). A supportive institution for implementing student-centered teaching can support research-based teaching practices (Nghia, 2017). Further studies are needed that investigate teaching beliefs and the relationship with actual enacted teaching practices (Li, 2013). A change in beliefs will not necessarily lead to a change in teaching practice (Assen, 2016). Additional research can help to better understand the complex relationship between beliefs and practices and how the context of the environment shapes these (Li, 2013).

Self-reporting on Teaching Practices

Many studies rely on participants’ self-reporting data. This method is the most feasible in many situations. It relies on the least amount of resources such as trained researchers, compensation for work, and time involved in work. Moreover, self-reporting is flexible. Participants can self-report at their convenience during any time that fits into their schedule. For these reasons self-reporting by research participants is widely used (Koziol & Burns, 1986; Lam & Bengo, 2003; Ross et al., 2003; Speer, 2005; Wieman, 2015; Williams et al., 2015).

There have been mixed reports as to how accurately self-reporting instruments capture teaching practices (Koziol & Burns, 1986; Lam & Bengo, 2003; Ross et al., 2003). After review of several studies, Ross et al. (2003) summarize "studies examining the accuracy of teacher self-reports present mixed results, in part because of defects in study design" (p. 346). Furthermore, research suggests that there are ways to improve accuracy in self-reporting and evaluation of instruction. Koziol and Burns (1986) explain self-reports made by teachers have high accuracy when reporting on specific practices and when reporting on instructional practices that occur over a long period. Williams et al. (2015) recommend that the reporting instrument "be administered in its entirety and without modifying the items" (p. 12). Lam and Bengo (2003) recommend using multiple measurements and multiple methods to strengthen findings in instructional practices.

In 2015, Wieman authored a paper discussing the benefits of using the Teaching Practices Inventory which he created with Gilbert in 2014. He explains that the TPI describes all of the teaching elements within a course (Wieman, 2015). Wieman (2015) stated "data supports the general validity of the scoring rubric across [a] full range of disciplines, although with less specificity as to the size of the impact particular practices have" (p.14). He later discusses concerns of reliability of faculty self-reports by emphasizing that the TPI was designed to maximize the accuracy of faculty self-reporting (Wieman, 2015). Moreover, the inventory responses that he and his team checked during the development of the TPI were accurate (Wieman, 2015; Wieman & Gilbert, 2014).

Theoretical Framework

Kane et al. (2002) describe that "theories of action are based on a view of humans as agents acting purposefully on their environment" (p. 182). There are two types of theories of

action: espoused theory which consists of individuals attitudes, values, and beliefs (Argyris, 1995) and theory-in-use which is what each individual applies at that moment (Argyris, 1995). Li (2013) simplifies this and explains that espoused theories are what people state to be of value whereas theories-in-use are the components that govern what people actually do. Argyris (1995) explains, "there are often fundamental, systematic mismatches between individuals espoused and in-use designs" (p.20). Since there are frequent mismatches between espoused theories and theories in-use it is important that researchers consider both types of theories of action for a complete picture of motivators for behavior in teaching practices.

When espoused theories and theories-in-use match that person's actions the person's intentions are more easily understood (Li, 2013). Nonetheless, Li (2013) suggests that when a gap is noticed more reflection and explanation is required to understand the relationship between the theories in that instance. For this reason, it is important that participant reflection be part of the research process (Li, 2013).

In 2005, and again in 2008, Speer contended that inconsistencies between beliefs and teaching practices may be due to misconceptions of understanding shared terms between the researcher and the research participants. Speer (2005; 2008) promoted more in depth fine-grained analysis to ensure that misunderstandings did not exist. For example, ensuring that when a teacher stated they believed in group work the researcher and the teacher/research participant had a common definition of "group work." Furthermore, Speer (2005) asserts that with a common understanding and use of reflective interview processes inconsistencies between espoused beliefs and theories-in-use can be related. This process may mitigate the discrepancy between beliefs and practices while simultaneously expanding on the alignment between them.

Ernest (1994) described "espoused and enacted" models which connected teaching beliefs to teaching practices for secondary level mathematics teachers (see Figure 1 above). These models align with Argyris's (1995) theories of action where Ernest's espoused model corresponds to Argyris's espoused theories and Ernest's enacted model corresponds to Argyris's theories-in-use. These frameworks appear to be consistent. So, there is a precedent for a framework of theories of action used in the context of mathematics education. However, it appears that Ernest's model and Argyris's theory have not been leveraged to their full potential. Several researchers have recognized a lack of an overarching theoretical basis for studies investigating the relationships between teaching beliefs and teaching practices (Kane et al., 2002; Li, 2013; Speer, 2005). Kane et al. (2002) specifically argue for more research at the university level that explores the connection between espoused beliefs and teaching practices.

The goal of this study is to use mixed methods to connect beliefs and teaching practices for tertiary instructors through the lens of Argyris's theories of action. The study will draw on more current research, e.g. Speer, 2008 and Li, 2013, to critically examine instructor's beliefs and enacted practices through this framework. Particularly, by using reflective interviewing techniques to establish greater interpretation between teaching beliefs and teaching practices for post-secondary mathematics instructors. This study will connect espoused theories and theories-in-use through multiple measures while also working to better understand inconsistencies described in previous research between beliefs and practices (Kane et al., 2002; Speer 2008; Speer 2005).

Chapter 3

Methods

Design

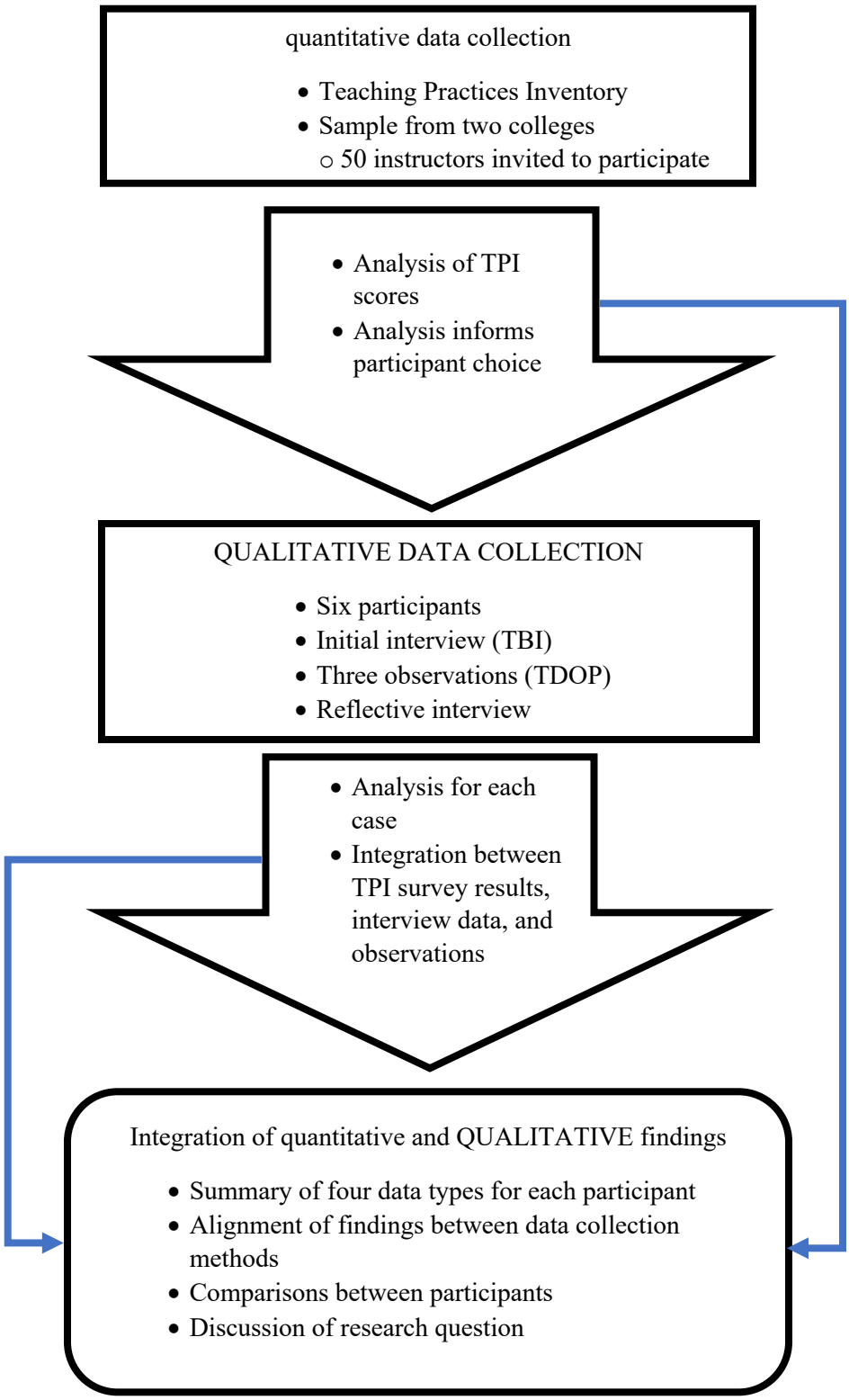
This research study implemented an explanatory sequential mixed methods design with a case selection and case study variant (quant → QUAL [Case Study]). The goal of this research study is to bridge the existing gap in literature between what is known about the teaching practices of undergraduate mathematics faculty and what is understood about teaching beliefs of undergraduate mathematics faculty.

The research study began with quantitative data collection through the administration of the Teaching Practices Inventory (TPI; Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014) within the mathematics department at two large colleges in a metropolitan area in the Southwestern portion of the United States. Scores from the TPI were divided into three categories based on use of a similar amount of research-based teaching practices. Descriptive statistics were analyzed for the TPI survey data. Next, two participants from each of three subdivisions were purposefully sampled (Creswell & Plano Clark, 2018; Krathwohl, 2009) for the qualitative portion of the study. This created six participants for qualitative data collection. Qualitative data collected for each participant was treated as a case study of that individual participant. The researcher had each participant take part in two semi-structured interviews. One interview was conducted at the beginning of the semester as an initial interview using the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007). The second interview occurred at the end of the semester as an exit/reflective interview. Three classroom observations following the Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013) took place between the initial and exit interviews.

Initial interviews were coded using rubrics that were established by Luft and Roehrig (2007) in accordance with the TBI, exit interviews were coded using a constant comparative method (Corbin & Strauss, 1990), and classroom observations were analyzed using codes established with the TDOP (Hora & Ferrare, 2013). These processes are explained in more detail below. Analysis of data focused on teacher practices and teacher beliefs about teaching practices. Furthermore, classroom observations were analyzed to determine whether practices observed in the classroom align with self-reported practices in the TPI survey and/or the beliefs discussed during participant interviews. Member checking was used during the reflective interview to establish trustworthiness in reporting. Figure 2 provides a summary of the explanatory sequential design.

Figure 2

Diagram for the Explanatory Sequential Structure of the Research Study



Participants

First, a voluntary sample of undergraduate mathematics faculty at the chosen colleges were recruited to participate in the quantitative stage of the research study. The researcher wished to obtain as many participants in the two math departments as possible. The undergraduate math teaching faculty sampled for the TPI survey are defined as an assistant professor, associate professor, professor, faculty-in-residence, part-time instructor, or graduate assistant who is teaching at least one undergraduate mathematics class during the Fall 2021 semester as a lead instructor (graduate assistants who are discussion leaders or teaching assistants working under another professor were excluded).

The second phase of the study (qualitative) consisted of case selected participants based on the TPI (quantitative) survey results. All quantitative participants received a score on the TPI survey. TPI survey scores range from 0 to 69. Score ranges formed three categories: low, moderate, and high. The score values for each category were determined by the range of scores in the data collected. Since higher scores on the TPI correspond to higher use of research-based teaching practices (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014), participants were grouped into the score categories based on analysis of the survey data. Using case selection (Creswell & Plano Clark, 2018), two participants from each of the categories were selected to participate in qualitative interviews and observations. This generated six faculty members to complete the qualitative component of the research study. Case selection is a form of purposeful sampling. Krathwohl (2009) explains, “purposive sampling is most often used in qualitative research to select those individuals or behaviors that will better inform the researcher regarding the current focus of the investigation” (p. 172).

Disclosure/Informed Consent

The researcher gained approval from the Institutional Review Board at the researcher's own university as well as obtaining additional approval by the respective Institutional Review Boards at the colleges where data was collected. All participants were informed of the intentions of the research study. Kvale and Brinkmann (2009) explain: "informed consent entails informing the research participants about the overall purpose of the investigation and the main features of the design, as well as of any possible risks and benefits from participation in the research project" (p. 70). Consent forms were provided to all participants to ensure comfortability with responding to survey questions, being audio recorded during interviews, and being audio recorded during classroom observations. During the first classroom observation for each participant, students were notified that the researcher was present to observe the actions of the instructor. Lastly, pseudonyms and randomized pronouns were created and used in all published research so that the participants will remain anonymous.

Data Collection

Data was collected in two phases. Quantitative data was collected during the first phase through the administration of the Teaching Practices Inventory (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014). Qualitative data was collected during the second phase through an iterative process of interviews and classroom observations. Each qualitative participant was interviewed twice and observed three times during the span of the Fall 2021 semester, see Table 1 (below) for the data collection timeline.

Table 1

Data Collection Timeline

Fall 2021 Semester	Data Collection Method/ Intervention
Aug. 3- Sept. 21	Teaching Practices Inventory
Sept. 6 - Sept. 14	Interview 1
Sept. 14 - Sept. 23	Observation 1
Sept. 27 - Oct. 7	Observation 2
Oct. 12 - Oct. 22	Observation 3
Nov. 8 - Nov. 17	Exit Interview

Teaching Practices Inventory/Survey (Quantitative)

The Teaching Practices Inventory (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014; Appendix A) is a 74-item list of teaching practices that are commonly used by tertiary STEM instructors. The listed teaching practices are divided into eight categories:

1. Course Information- this category represents teaching practices such as providing lists of learning topics and written learning goals for students.
2. Supporting Materials- this category includes teaching practices such as providing video clips, simulations, or lecture notes (which can be complete, outlines, or fill-in-the-blank).
3. In-Class Features and Activities- this category includes teaching practices such as discussing why material is useful, student presentation activities, asking students questions, and giving time for students to ask questions.

4. Assignments- this category includes teaching practices such as assigning problems sets or homework, assigning papers or projects, and providing written feedback when correcting assignments.
5. Feedback and Testing- this category includes teaching practices such as encouraging students to complete one-on-one meetings for feedback, giving partial credit on exams for questions that require an explanation of thinking, providing answer keys to past exams, and providing explanation for the breakdown of points on exams.
6. Other- this category encompasses elements of teaching such as diagnostics, pre/post testing, and new methods that may not be included in the survey. Examples of teaching practices in the "other" category include assessments at the beginning of the course, having students complete pre/post surveys of interests or course feedback, and new teaching methods with measurements of effect on learning.
7. Training and Guidance of Teaching Assistants- this category includes practices such as training teaching assistants and instructors meeting with their teaching assistants to discuss learning difficulties that students are having with current material.
8. Collaboration or Sharing in Teaching- this category includes practices such as reading literature about teaching that is relevant to the courses the instructor teaches, having discussions about teaching and teaching practices with colleagues, and sitting in on another instructor's course.

Participants indicated teaching practices that they used by checking boxes next to the teaching practice. Some of the survey questions required a short answer. There were also spaces provided for optional short answers.

Quantitative Survey Procedures.

All instructors that were identified as meeting the criteria for participation in the study were emailed an invitation to participate in the survey. The invitation included an introduction to the study, all pertinent information to the study, the informed consent waiver, and an electronic link to a copy of the TPI survey on *Qualtrics*. The *Qualtrics* survey had the participants acknowledge their consent before they began the survey. Survey responses were then received electronically through *Qualtrics*. The TPI survey on *Qualtrics* was open for a four-week window. Two email reminders were sent to the potential participants who had not completed the survey during the second and third week of the window.

Interviews (Qualitative)

The researcher interviewed each of the case selected faculty participants twice during the semester. The initial interview at the beginning of the semester followed the semi-structured Teacher Beliefs Interview (Luft & Roehrig, 2007). The exit interview at the end of the semester was tailored to each case, using reflective interview practices (Speer, 2005). These interviews focused on discussing the alignment between each teacher's self-reported practices, teaching beliefs (described during their initial interview), and the teacher's observed teaching practices. A timeline of the data collection is provided above in Table 1.

Interview Procedures.

After the analysis of the TPI survey in phase one the researcher selected instructors to participate in the qualitative portion of the study. After participant identification (based on TPI results) the researcher invited instructors to participate through the institution's assigned emails. Two instructors were contacted in each category.

Interviews were audio recorded so the interviews could be transcribed verbatim. The researcher also took notes on the participant responses. Interviews were approximately 30-45 minutes long. Interviews occurred through video conferencing.

The first interview followed a modified version of the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007). The TBI has been modified to fit a mathematics context instead of the science context in the original TBI design. Luft and Roehrig (2007) used the TBI with pre-service mathematics teachers and determined that the TBI was generalizable and valid. The modified Teacher Beliefs Interview, which has been used in prior research with university instructors (Moore et al., 2015), was comprised of these seven questions adapted from Luft and Roehrig (2007, p. 43):

1. How do you maximize student learning in your classroom? (Teaching practice)
2. How do you describe your role as a teacher? (Teaching practice)
3. How do you know when your students understand? (Assessment)
4. In the [class] setting, how do you decide what to teach and what not to teach? (Teaching practice)
5. How do you decide when to move on to a new topic in your [course]? (Assessment)
6. How do your students learn [mathematics] best? (Student learning)
7. How do you know when learning is occurring in your [class]? (Student learning)

A supplemental eighth question was added to allow participants to discuss any other thoughts that they felt were relevant:

8. Do you have any final thoughts or comments that you would like to share in regard to your teaching practices?

The second interview followed reflective interview practices (Speer, 2008). This method provided the researcher an opportunity to confirm shared understanding of terms and ideas. Moreover, the researcher and the participant discussed alignment and discrepancies between the reported teaching practices, initial interview, and the classroom observations.

Classroom Observations (Qualitative & Quantitative)

In addition to the initial and exit interview, three classroom observations were conducted for each of the faculty participants. Observations took place in lower level mathematics courses (i.e. Calculus I or lower). The participant chose which of their classes they would like to be observed while teaching. For example, if an instructor was teaching Calculus I and College Algebra during Fall 2021 the instructor was asked their preference to which of their courses was to be observed prior to the first observation. After which, all three observations occurred in the same mathematics class. The instructors were asked to let the researcher observe what they would describe as a typical class. Addy and colleagues (2015) state, "this method of data collection is important because perceived teaching beliefs of faculty have been shown to sometimes be incongruent with enacted practice" (p. 95).

Observation Procedures.

The first of the three classroom observations occurred one to two weeks after each of the participant's initial interviews. The second and third observations occurred approximately every other week after the first classroom observation (see data collection timeline in Table 1). Data was collected during the classroom observations using the Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013). Additionally, classroom observations were audio recorded so they could be reviewed. Some classroom observations occurred virtually as some courses were still held remotely due to the COVID-19 pandemic.

The TDOP (see Appendix B) was designed to "capture dynamics among *teaching methods* (e.g. lecture, small-group discussion), use of *instructional technology* (e.g. clickers, PowerPoint), and students' *cognitive engagement* (i.e. the types of student thinking evoked by the instruction)" (Hora & Ferrare, 2013, p. 215). Hence, the TDOP comprises three categories: teaching methods, cognitive engagement, and instructional technology. Additionally, each category has its own set of codes; codes may be modified to fit a mathematics classroom context (Hora & Ferrare, 2013). The codes are described in the next section.

The researcher sat in a location of the classroom that allowed a full view of the room and was non-distracting to students (as noted above, some classroom observations occurred virtually). The researcher circled codes when they were observed during specified time intervals starting at the beginning of class time and continuing through the entire class period. The TDOP used by Hora and Ferrare (2013) employs five-minute intervals over a 30 minute period; the period length for this research was modified to five-minute intervals over the 75 or 80 minute class period.

TDOP codes.

An important aspect of the TDOP is that it was designed for university classes. Moreover, the codes for the instrument were identified by surveying researchers in math and science education and math and science faculty who reviewed a proposed list of codes for each category (Hora & Ferrare, 2013). The three tables below (Table 2, Table 3, and Table 4) describe the codes within each category.

Table 2 specifically describes the codes for the TDOP which are associated with teaching methods. These codes were used to capture teaching practices performed during classroom observations.

Table 2

Teaching Dimensions Observation Protocol Codes for Teaching Methods

Teaching Methods	Example
Lecture (LEC)	Instructor verbally presents factors or concepts.
Multimedia (MM)	Instructor uses more than one medium of expression or communication
Illustration (IL)	Instructor uses a story or anecdote to describe a fact or concept
Demonstration (DEM)	Instructor uses a physical demonstration of a phenomenon using experimental or other equipment
Worked out problems (WP)	Instructor engages in the active solving of numerical problems
Small-group work (SGW)	Instructor directs students to work in pairs or small groups
Desk work (DW)	Instructor directs students to work alone at their desks
Case study (CS)	Instructor presents a case for detailed elaboration and analysis
Online techniques (OT)	Instructor actively draws on the course website
Rhetorical question	Instructor poses a question as a figure of speech for illustrative or persuasive reasons
Display conceptual questions (DCQ)	Instructor poses a question to obtain information about student comprehension about concepts
Display algorithmic questions (DAQ)	Instructor poses a question to obtain information about student comprehension about algorithms or computations
Comprehension question (CQ)	Instructor poses a question to assess students' generalized understanding of a previous topic
Novel question (NQ)	Instructor poses a question to which he or she does not know the answer
Whole-class discussion (CD)	Instructor and students engage in back-and-forth discussion

Note. Adapted from "Instructional Systems of Practice: A Multidimensional Analysis of Math and Science Undergraduate Course Planning and Classroom Teaching," by M. T. Hora and J. J. Ferrare, 2013, *Journal of the Learning Sciences, 22,* p. 225. (https://doi.org/10.1080/10508406.2012.729767)

Table 3 describes the codes for the TDOP that specifically observe cognitive engagement within the classroom. These codes were used as an indication to determine the occurrence of student-centered teaching practices and teacher-centered practices.

Table 3

Teaching Dimensions Observation Protocol Codes for Cognitive Engagement

Cognitive Engagement	Example
Receive/memorize information (RM)	Students hear facts and information with expectations only that they will internalize and recall information
Understanding problem solving (PS)	Students follow solution paths or other analytic processes
Creating ideas (CR)	Students engage in brainstorming activity at their desks and report back to the class with their ideas
Integrating ideas (IN)	Students actively reflect on prior knowledge and its relationship to new information
Connecting to the real world (CN)	Students relate course material to common experiences or aspects of their daily lives

Note. Adapted from "Instructional Systems of Practice: A Multidimensional Analysis of Math and Science Undergraduate Course Planning and Classroom Teaching," by M. T. Hora and J. J. Ferrare, 2013, *Journal of the Learning Sciences, 22,* p. 226. (https://doi.org/10.1080/10508406.2012.729767)

Table 4 describes the codes for the TDOP that specifically involve the use of instructional technology for teaching. Technology use is not a primary topic of this research study. However,

these technology codes were used as indicators of student-centered or teacher-centered teaching practices.

Table 4

Teaching Dimensions Observation Protocol Codes for Instructional Technology

Instructional Technology	Example
Demonstration equipment (D)	The instructor walks through calculator use
Computer and slides (LC)	A computer connected to a digital projector that displays slides on a screen
Posters (PO)	Posters on the wall
Book (B)	A textbook or other book physically used by the instructor
Pointers (P)	Laser pointers used to shine a focused light on a screen
Clicker response systems (CL)	Handheld devices with which students indicate answers to multiple-choice questions projected onto a screen
Overhead Projector/Elmo (OP)	A projector that displays images or writing on transparent sheets or plastic
Digital Tablet (T)	A computer that displays images or writing directly onto a screen
Blackboard/Whiteboard (BB)	A blackboard or whiteboard hung on walls at the front of a classroom
Miscellaneous object (OB)	A miscellaneous instructional artifact not captured by other codes

Note. Adapted from "Instructional Systems of Practice: A Multidimensional Analysis of Math and Science Undergraduate Course Planning and Classroom Teaching," by M. T. Hora and J. J. Ferrare, 2013, *Journal of the Learning Sciences, 22,* p. 227. (https://doi.org/10.1080/10508406.2012.729767)

Data Analysis

Data from all three components of the study were analyzed separately. All three components were integrated for each of the case-selected individuals forming a case study for each of those participants. Lastly, case studies were compared to one another and to the entire sample of quantitative data from the first phase.

Teaching Practices Inventory/Survey (Quantitative)

The Teaching Practices Inventory (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014) has been published with an accompanying scoring rubric. The scoring rubric yields scores such that higher scores correspond to higher use of research-based teaching practices. The minimum score is 0 and the maximum score is 69. Note that the maximum score increased from 67 to 69 in the updated 2018 version of the TPI, as two more research-based practice items were added to the inventory (Carl Wieman Science Education Initiative, 2018). The participants completed the TPI on *Qualtrics*; afterwards the researcher scored each survey. Section scores were calculated based on the eight categories of the TPI. Overall scores and section scores were analyzed using descriptive statistics.

Interviews (Qualitative)

Interviews were transcribed word for word. After, they were coded through the use of an existing rubric which was designed by Luft and Roehrig (2007) in conjunction with their design of the Teacher Beliefs Interview. The rubric is specialized for each of the seven questions. The rubric for each question classifies responses on a continuum between teacher-centered to student-centered beliefs. The continuum has five categories: traditional, instructive, transitional, emerging constructivist, and experienced constructivist (Table 5; Luft & Roehrig, 2007; Moore et al., 2015). All eight questions were coded, and themes were sought out by using a constant

comparative method (Corbin & Strauss, 1990). This was aided by the use of *MAXQDA*, an online research system used for analyzing qualitative data. The two interviews each participant completed were compared for similarities and differences such as common themes or changes.

Table 5

Teacher Beliefs Interview Rubric Category Descriptions

Category	Description
Traditional	Focus on information, transmission, structure, or sources.
Instructional	Focus on providing experiences, teacher-focus, or teacher decision.
Transitional	Focus on teacher/student relationships, subjective decisions, or affective response.
Emerging Constructivist	Focus on collaboration, feedback, or knowledge development.
Experienced Constructivist	Focus on mediating student knowledge or interactions.

Note. Adapted from "Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview," by J. A. Luft and G. H. Roehrig, 2007, *Electronic Journal of Science Education, 11(2),* p. 54 and from "Changes in Faculty Members' Instructional Beliefs While Implementing Model-Eliciting Activities," by T. Moore, S. Guzey, G. Roehrig, M. Stohlmann, M. Park, Y. R. Kim, H. Callender, and H. J. Teo, 2015, *Journal of Engineering Education, 104(3),* p. 287.

Classroom Observations (Qualitative & Quantitative)

Classroom observations were coded while the researcher observed the class. The researcher identified appropriate codes in the Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013) during timed intervals while also taking notes. Audio recordings of the class observations were referenced for clarification or verification as needed. The researcher reviewed the coded observations to calculate frequency of coded behaviors for each instructor using spreadsheets to track the data for each instructor. Next, the three observations for each instructor were compared to determine similarities and differences.

Integration

The first point of integration occurred between quantitative data collection and qualitative data collection through the use of quantitative data that informed the qualitative case selection. The second point of integration occurred in several ways.

After the survey, interview, and observational data was organized and analyzed separately, the researcher compared and contrasted the survey data, observational data, and the interview data. Survey data was transformed into qualitative themes based on common teaching practices that instructors identified using in the Teaching Practices Inventory. Then, the three types of data were evaluated together for similarities and differences. Findings for each instructor were evaluated. In particular, the researcher explored the relationship between teaching beliefs (interview data), self-reported teaching practices (survey data), and observed teaching practices (classroom observation data) for each instructor discussing the alignment or differences in that instructor's responses.

After the investigation for each instructor was completed, the researcher looked for common themes and differences between instructors. First, making comparisons between

instructors that were in the same TPI grouping. Next, by making comparisons of findings between instructors in different TPI groupings.

Lastly, the researcher compared and contrasted themes found between the small instructor group that completed all three components of data collection and the generalized findings for the entire department based on the quantitative data collected through the Teaching Practices Inventory which was completed by the larger sample.

Reporting

The findings from this study were reported in the following ways. The researcher used a side-by-side discussion to explain both the quantitative and qualitative data. Tables were provided for the statistical analysis of the data. Additionally, frequency tables were used to create visual representations of the TPI survey data and for the frequency of codes created during classroom observations.

Excerpts from interviews were compiled to exemplify themes, illustrate quantitative findings, and demonstrate any inconsistencies between the three components of the study. The researcher used member checking (Lincoln & Guba, 1985) for the interview component of the study to ensure that results summarized by the researcher represented the participants' beliefs in an authentic manner. In this instance, each participant was provided with a summary of their responses to the initial interview during the reflective interview.

Through the use of narrative description, tables, and excerpts from the interviews this research study emphasized the connection between teaching beliefs and teaching practices bridging two highly related topics in a study that encompassed several components of data. The use of a mixed-methods design allowed the researcher to analyze the relationships between teaching beliefs and teaching practices for undergraduate mathematics faculty.

Chapter 4

Data Analysis and Results

This chapter summarizes the analysis of data collected throughout the length of the study. The chapter is divided into five main sections. The first section of the chapter describes the statistics of scores for the Teaching Practices Inventory (TPI; Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014) for all of the participants who completed the survey. The second section of the chapter describes the selection of the qualitative participants and their respective TPI scores with corresponding statistics. The third section of the chapter describes participant responses in the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007) and explains a cross-case summary of the participants' responses. The fourth section of the chapter discusses the results of each participant's teaching observations and relative frequencies of observed instructor practices following the Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013). The fifth section of the chapter describes each participant's reflective interview and explains the alignment of responses between all four data sources for each participant.

Teaching Practices Inventory Statistics

The Teaching Practices Inventory survey was electronically distributed to a sample of 50 collegiate mathematics faculty via *Qualtrics*. The Teaching Practices Inventory (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014; Appendix A) is a 74-item list of teaching practices that are commonly used by tertiary STEM instructors. Twenty-two participants completed the informed consent form. Twenty-one of the instructors chose to participate and one did not.

The TPI survey responses were scored using the rubric created by Wieman and Gilbert (2014). The scoring rubric awards positive points for the teaching practices in the survey that

correspond to research-based teaching practices. The survey also lists common teaching practices; however, if the practice (although common) is not research-based, that practice earns 0 points. There are 53 items on the TPI that contribute to points. Each of the 53 items are supported by research that indicates that those practices are associated with an improvement in learning (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014). The maximum survey score possible is 69 points, and the minimum survey score possible is 0 points.

In the case of the 21 participants who completed the survey, there was a minimum score of 21 points and a maximum score of 52 points. The range of respondent scores was 31 points. The average score was 35.14 points, and the median score was 35 points. The lower quartile was 30 points, and the upper quartile was 40 points. The standard deviation of scores was 7.722 points. There were no outliers in the respondents' scores.

Teaching Practices Inventory Section Scores

There are eight categories in the TPI. Each category was scored separately to create section scores. The lowest possible score in all sections is 0 points. The maximum score in each category varies. The teaching practices in each category may fall into more than one of the themes described below. These themes represent the research-based practices that support student learning or the research-based practices that support instructor effectiveness. The categories are Course Information, Supporting Materials, In-Class Features and Activities, Assignments, Feedback and Testing, Other, Training and Guidance of Teaching Assistants, and Collaboration and Sharing in Teaching. The first four categories contain teaching practices that support student learning. The Feedback and Testing category and the Other category both contain teaching practices that support student learning and support instructor effectiveness. Both

the Training and Guidance of Teaching Assistants category and the Collaboration and Sharing in Teaching category contain practices that support instructor effectiveness.

The first section is Course Information. The practices in this category that are research-based are related to knowledge organization (e.g. topics to be covered) and student motivation (e.g. affective goals). The maximum possible score for this section is 6 points. The lowest participant score was 0 points, and the highest participant score was 4 points. The average score was 2.143 points, and the median score was 3 points. The standard deviation was 1.153 points.

The second section is Supporting Materials. The research-based practices contained in this category are described by the following themes: knowledge organization (e.g. lecture notes), reducing cognitive load (e.g. completed examples), motivation (e.g. articles from research for students), practice (e.g. practice exams), and feedback (e.g. solutions to homework assignments). The maximum possible score for this section is 9 points. The lowest participant score was 3 points, and the highest participant score was 7 points. The average score was 4.429 points, and the median score was 4 points. The standard deviation was 1.121 points.

The third section is In-Class Features and Activities. The research-based practices in this category are described by the following themes: knowledge organization (e.g. time spent pausing to ask for questions), reducing cognitive load (e.g. students read material prior to class), motivation (e.g. discussions about why material is useful), practice (e.g. small-group discussions), feedback (e.g. pausing to ask for questions), and metacognition (e.g. reflective activity at the end of a lesson). The maximum possible score for this section is 15 points. The lowest participant score was 1 point, and the highest participant score was 13 points. The average score was 6.667 points, and the median score was 7 points. The standard deviation was 3.337 points.

The fourth section is Assignments. The research-based practices for this category are described by the following themes: practice (e.g. homework that contributes to the course grade), feedback (e.g. students see graded assignments and exams), and group learning (e.g. encouragement for students to collaborate). The maximum possible score for this section is 6 points. The lowest participant score was 0 points, and the highest participant score was 6 points. The average score was 3.81 points, and the median score was 4 points. The standard deviation was 1.632 points.

The fifth section is Feedback and Testing. The research-based practices for this category are described by the following themes: motivation (e.g. students are explicitly encouraged to meet individually with the instructor), practice (e.g. assessment questions require explanation of reasoning), feedback (e.g. breakdown of course grade), and feedback on instructor effectiveness (e.g. repeated feedback from students). The maximum possible score for this section is 13 points. The lowest participant score was 5 points, and the highest participant score was 12 points. The average score was 9.19 points, and the median was 10 points. The standard deviation was 2.182 points.

The sixth section is Other, which describes several research based-teaching practices that do not fit within another category. This includes using pre/post tests, pre/post surveys, and trying new teaching methods. The research-based practices for this category are described by the following themes: motivation (e.g. students are provided with choices in their own learning), metacognition (e.g. students have opportunities for self-evaluation), connections to student's prior knowledge and beliefs (e.g. assessment at the beginning of the course), and feedback on effectiveness (e.g. the instructor uses consistent measures of learning that are repeated). The maximum possible score for this section is 10 points. The lowest participant score was 0 points,

and the highest participant score was 8 points. The average score was 3.28 points, and the median score was 3 points. The standard deviation was 2.322 points.

The seventh section is Training and Guidance of Teaching Assistants. The research-based practices contained in this category are related to gaining relevant knowledge and skills. Examples include training for teaching assistants and instructor-teaching assistant meetings about student performance and difficulties. The maximum score possible for this section is 4 points. However, an instructor indicating that they did not have teaching assistants on the TPI earned 3 points. Wieman and Gilbert (2014) explain that the awarding of 3 points is not due to an educational benefit, the points are simply to normalize between courses that do and do not have teaching assistants. None of the participants in this study had teaching assistants for their courses. Therefore, all of the participants received a score of 3 points.

The eighth section is Collaboration or Sharing in Teaching. The research-based practices contained in this category are related to gaining relevant knowledge and skills. These practices include discussing how to teach a course with colleagues and reading literature about teaching and learning that is relevant to the courses that the instructor teaches. The maximum score for this section is 6 points. The lowest participant score was 0 points, and the highest participant score was 5 points. The average score was 2.667 points, and the median score was 2 points. The standard deviation was 1.426 points.

Participant Choice for Qualitative Data Collection

Though 21 participants completed the TPI, when participants were chosen to complete the interviews and classroom observations, only 10 participants had completed the TPI. At the end of a two-week period in which the survey was open, the survey had been completed in full by 10 respondents. The researcher decided to move forward in choosing participants in order to

adhere to the research timeline to assure that the qualitative data could be collected before the end of the semester. The survey was scored for each of the 10 participants using the rubric created in conjunction with the TPI (Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014).

One respondent was eliminated from the qualitative sample pool because the instructor taught uncommon math courses that are specialized for a particular degree program.

For the nine remaining respondents, the scores ranged from 21-39 points. This range was divided into three sub-ranges, Low: 21-26, Medium: 27-32, High 33-39. Two instructors were chosen from each of the three sub-ranges to be asked to participate in the qualitative portion of the study. Furthermore, the nine instructors taught a variety of 100 level math courses. For this reason, instructors were chosen so at least two instructors in the set taught the same course. Instructors who taught the same course did not necessarily fall into the same sub-score range. Lastly, the participants were chosen so there would be three qualitative participants from each of the two collaborating colleges.

The six chosen candidates were emailed, asking for their continued participation for the qualitative portion of the study. After a week-long period, five of the six participants had responded in agreement to participate in the qualitative portion of the study. As the sixth participant had not yet confirmed participation by this time, a seventh participant was asked. This participant taught the same course as the sixth participant, and their scores were only one point apart. However, the seventh participant was from college two, whereas the sixth participant was from college one. The seventh participant agreed to join the qualitative study. Shortly thereafter, the sixth participant responded with their willingness to participate as well. Therefore, both the sixth and seventh participants were included in the qualitative portion of the research.

In conclusion, seven participants were chosen and completed the qualitative portion of the study. Three from college one and four from college two. Two of the participants were from the low score range, two from the medium score range, and three from the high score range. Two of the participants taught Fundamentals of College Math, two participants taught Precalculus I, and three participants taught College Algebra. However, as qualitative data collection began, it was determined due to scheduling that the third College Algebra instructor would have their Precalculus II course observed instead.

TPI Scores for Qualitative Participants

The TPI score and the section scores for each of the seven qualitative participants are described below. All of the qualitative participants scored 3 out of 4 in the Training and Guidance of Teaching Assistants section of the TPI. This score was due to the fact that none of the qualitative participants had teaching assistants for their courses. Recall that none of the study participants had teaching assistants for their courses. Thus, as per the TPI scoring rubric all participants (including the qualitative participants) score was normalized so they received 3 points in that section (Wieman & Gilbert, 2014). For this reason, the score is noted for each participant, but that section is not discussed further. Note that each participant, to maintain anonymity, was assigned a pseudonym and randomized pronouns. Table 6 has the total scores and sub scores for each participant on the TPI. The numbers in parentheses are the maximum scores for each section.

Table 6

Summary of Participants' TPI Scores

TPI Section	Finn	Blair	Riley	Taylor	Harlow	Casey	Addison
Course Information	3 (6)	4 (6)	3 (6)	3 (6)	3 (6)	1 (6)	3 (6)
Supporting Materials	5 (9)	4 (9)	4 (9)	4 (9)	5 (9)	3 (9)	5 (9)
In-Class Features and Activities	2 (15)	7 (15)	10 (15)	2 (15)	1 (15)	10 (15)	5 (15)
Assignment	6 (6)	5 (6)	5 (6)	2 (6)	2 (6)	4 (6)	4 (6)
Feedback and Testing	10 (13)	10 (13)	7 (13)	5 (13)	6 (13)	9 (13)	9 (13)
Other	1 (10)	4 (10)	2 (10)	0 (10)	1 (10)	3 (10)	0 (10)
Teaching Assistants Training	3 (4)	3 (4)	3 (4)	3 (4)	3 (4)	3 (4)	3 (4)
Collaboration and Sharing	2 (6)	2 (6)	1 (6)	2 (6)	3 (6)	3 (6)	0 (6)
Total score	32 (69)	39 (69)	35 (69)	21 (69)	24 (69)	36 (69)	29 (69)

Finn's TPI Scores

Finn teaches Fundamentals of College Math courses. These courses were held in person during the semester of this study. Finn's score was 32 out of 69 on the TPI. His score on the TPI was 3.14 points below the average score and 3 points below the median score. This indicates that Finn uses a fair amount of research-based teaching practices in his classroom. Finn scored all of the respective points in the Assignment section. He also scored most of the respective points in the Feedback and Testing section. He scored more than half of the respective points in the Supporting Materials section. Finn also scored half or the respective points in the Course Information section. Finn only scored 1 point in the Other section.

Blair's TPI Scores

Blair teaches Fundamentals of College Math- Corequisite courses. These courses were held remotely using a virtual system for the semester of the study. Blair scored 39 out of 69 on the TPI. Her score on the TPI was 3.86 points above the average score and 4 points above the median score. Her score indicates that she uses a considerable amount of research-based practices in the courses that she teaches. Blair scored most of the respective points in the Course Information section, the Assignment section and the Feedback and Testing section. She scored just less than half of the respective points in the Supporting Materials section and in the In-Class Features and Activities section.

Riley's TPI Scores

Riley teaches Precalculus II. Her courses were held remotely using a virtual classroom environment during the semester of the study. Riley's score was 35 out of 69 on the TPI. Her score was 0.14 points below the average score, and she earned the same score as the median. Riley's score indicates that she uses a medium amount of research-based teaching practices in her classes. Riley scored most of the respective points in the Assignment section. She also scored over half of the respective points in the In-Class Features and Activities section and the Feedback and Testing section. She scored exactly half of the respective points in the Course Information section. Riley only scored 1 point in the Collaboration and Sharing in Teaching section.

Taylor's TPI Scores

Taylor teaches Precalculus I courses. Her courses were conducted in person during the semester of this study. Taylor's score on the TPI was a 21 out of 69. Her score was 14.14 points below the average score and 14 points below the median score. Taylor's score indicates that she

uses a low amount of research-based teaching practices in her courses. Of Taylor's point break down, she scored the most points in the Feedback and Testing section. She also scored half the respective points in the Course Information section and almost half of the respective points in the Supporting Materials section. She did not score any points in the Other section.

Harlow's TPI Scores

Harlow teaches Precalculus I courses. Her courses were held remotely using a virtual environment for meetings during the semester of the study. Harlow's score was 24 out of 69 on the TPI. Her score was 11.14 points below the average score and 11 points below the median score. Harlow scored over half of the respective points in the Supporting Materials section. She scored half of the respective points in the Course Information section and in the Collaboration and Sharing in Teaching Section. Harlow scored almost half of the respective points in the Feedback and Testing Section. She only scored 1 point in both the In-Class Features and Activities section and the Other section.

Casey's TPI Scores

Casey teaches College Algebra courses. His courses were held in person during the semester of this study. Casey scored a 36 out of 69 on the TPI. His score was 0.86 points above the average score and 1 point above the median score. Casey's score indicates that he uses a moderate amount of research-based teaching practices in his classes. Casey scored more than half of the respective points in the In-Class Features and Activities section, the Assignment section, and the Feedback and Testing section. He also scored half of the respective points in the Collaboration and Sharing in Teaching section. Casey only scored 1 point in the Course Information section.

Addison's TPI Scores

Addison teaches College Algebra. His classes this semester were held remotely using a virtual platform for meetings. Addison scored 29 out of 69 on the TPI. His score was 6.14 points below the average score and 6 points below the median score. Addison's score indicates that he uses some research-based teaching practices in his classes. Addison scored more than half of the respective points in the Supporting Materials section, the Assignment section, and the Feedback and Testing Section. He also scored half of the respective points in the Course Information section. Yet, he scored 0 points in both the Other section and the Collaboration and Sharing in Teaching section.

Teacher Beliefs Interviews (Initial Interviews)

At the beginning of the semester, the selected seven participants met with the researcher individually for the initial semi-structured interview. During this initial interview the researcher followed the questions from the Teacher Beliefs Interview (TBI) constructed by Luft and Roehrig (2007). The interview consisted of the following questions (Luft & Roehrig, 2007, p. 43):

1. How do you maximize student learning in your classroom? (Teaching practice)
2. How do you describe your role as a teacher? (Teaching practice)
3. How do you know when your students understand? (Assessment)
4. In the [classroom] setting, how do you decide what to teach and what not to teach? (Teaching practice)
5. How do you decide when to move on to a new topic in your [course]? (Assessment)
6. How do your students learn [mathematics] best? (Student learning)
7. How do you know when learning is occurring in your [class]? (Student learning)

A supplemental eighth question was added:

8. Do you have any final thoughts or comments that you would like to share in regard to your teaching practices?

Each participant's responses to the seven TBI questions were coded following the beliefs continuum rubric developed by Luft and Roehrig (2007) to coincide with the TBI. There are five categories for the rubric: Traditional, Instructional, Transitional, Emerging Constructivist, and Experienced Constructivist (Moore et al., 2015; Luft & Roehrig, 2007). The categories are on a continuum from teacher-centered to student-centered classroom instruction. A summary of each participant's response is provided below. The code for each question response is stated in parentheses at the end of each question summary. Additionally, a synopsis for the eighth question is provided.

Finn's TBI Responses

For the first question, maximizing student learning, Finn explained that he tries to present material as clearly and concisely as possible. If questions are asked, Finn tries to present the material in a different manner. Finn emphasized that there are always multiple ways to explain mathematics concepts, especially in 100 level courses. Finn also asserted the importance of allowing time for students to process the material and ask questions during class time. These answers indicate that Finn observes and responds to student behavior while still maintaining an environment of direct instruction. *(Instructional)*.

Finn characterizes himself as a guide for students. That his job as a teacher is to interpret the text by cutting through excess information and concentrating on major concepts. Finn also added that he is there to assist students in navigating through the topics that the students are

supposed to learn in the course. Finn's explanation demonstrates his focus on providing students with information and helping students understand the material. *(Instructional)*.

When asked how he knows when students understand, Finn initially conveyed that it is difficult to gauge in a classroom. However, Finn described relying upon facial expressions as a major factor in determining when the class is understanding. Finn continued, if there seem to be several confused expressions, he then reiterates the concept in a different way. Finn also listed other resources that he encourages his students to use. These supports comprise the various tutoring resources available on the campus, seeing the instructor during office hours, and being able to email the instructor questions. Finn described reiterating these resources to students as frequently as possible. Finn's explanation of knowing when students understand relied heavily upon non-verbal cues and the measures students should be taking if they are struggling to understand. This description establishes focus on students receiving information. *(Traditional)*.

Finn declared that objectives to teach are determined by the math department at his college. The goal is for lower-level math courses to maintain uniformity in requirements and the topics taught. For this reason, Finn is somewhat restricted in choosing what topics he teaches. However, Finn explained, "I want students to know and make sure to have those core concepts in my lectures." Then, if there is more time, Finn stated he will add depth to the concepts by providing specialized examples or applications of the core ideas. Finn concluded that his main goal is to ensure students are capable of performing well on the quizzes and tests that are given. Finn feels that the decisions in what objectives to teach are guided primarily by department curriculum. *(Traditional)*.

Finn's initial answer for deciding when to move on to a new topic in class is based upon the course schedule that he creates prior to the start of the semester. Nonetheless, Finn explained

that the schedule is tentative. So, his goal is to guarantee that core concepts are covered in enough detail for students to understand before moving on. Reiterating, Finn commented, "I try not to not move on until I have covered the core concepts and given the students opportunity to ask questions on any of the material or any of the examples presented during the lecture." Finn also starts his class each time by asking if there are any questions from the previous class or homework. Finn's schedule does rely on the tentative schedule, yet Finn does adjust pacing based on student questions and understanding. Additionally, Finn is willing to revisit old concepts for the benefit of the students. *(Emerging Constructivist)*.

In order to answer how students learn best, Finn first described his aim while teaching. Finn stated that students have different learning styles, so his approach is to go over the basics first. Finn further explained that he asks students to read the textbook sections and checks student understanding with quizzes. Finn uses questioning and discussion to keep students engaged during class. Lastly, Finn encourages students to visit office hours or to use tutoring resources to ask questions. Finn's response emphasizes that students should be practicing the problems that are discussed in class and other similar problems on the homework. *(Instructional)*.

To explain when learning is occurring in his classroom, Finn described watching students work on problems and listening to student responses to posed questions during class. Based on how the students answer questions and come to solutions indicates student learning. Finn said that another way he knows student learning is occurring is by the type of questions students ask. Finn elaborated that as learning takes place, the questions students ask change from basic questions about procedure to questions related to application or questions that tie into the next concept yet to be discussed. Lastly, Finn explained that as the lecture goes on, if more students begin responding to instructor posed questions and speaking out during lecture, that is a good

indication that learning is occurring. Finn's answer mainly references student feedback and interaction during the lesson. *(Emerging Constructivist)*.

In providing final thoughts, Finn explained he feels that his teaching style is more of a traditional one. Finn added that he tries to be flexible in presenting the material, although he mostly uses the projector and whiteboard. In conclusion, Finn commented he has received positive student feedback about how class is conducted, so he continues to teach in this traditional manner.

In summary, two of Finn's answers were coded as *traditional*, three responses were coded as *instructional*, and two were coded as *emerging constructivist*. Finn did not have any responses coded as *transitional* or as *experienced constructivist*. Finn's responses to the third question and fourth question were *traditional*. His responses to the first, second, and sixth questions were coded as *instructional*. In question five and seven, his responses were coded as *emerging constructivist*. Finn's responses to the TBI questions tend toward the teacher-centered side of the teacher-centered to student-centered beliefs continuum, as five of his seven responses were on that side of the spectrum.

Blair's TBI Responses

Blair stated that in order to maximize learning in the classroom she focuses on providing multiple ways for students to approach a problem. She wants students to realize there is creativity in mathematics. Blair has implemented mini-projects, so students have varied opportunities to demonstrate understanding of mathematics. Blair highlights using methods other than lecture and focuses on using multiple approaches to assess student understanding. *(Transitional)*.

In reply to describing her role as a teacher, Blair characterizes herself as a facilitator. She explained that as a teacher she strives to match the efforts of her students, and she does not wish for students to mechanically copy her instruction. Blair clarified that her goal is to support and coach students by guiding students through the content, as well as encouraging student skills such as notetaking and test taking. Blair's feedback illustrated a focus on relationships with students and student understanding of concepts. *(Transitional)*.

Blair elucidated multiple methods for assessing student understanding. First, Blair's students have multiple attempts to complete assignments, so Blair stated she can see student progression there. Secondly, Blair disclosed the value of creating assessment questions that require conceptual knowledge as opposed to rote memorization. Next, Blair expressed the difficulties that the remote environment creates by not being able to see students' faces. To solve this complication, Blair encourages students to use the reaction icons in the video chat environment. Blair stated she continually reminds students that she does not know if the student needs help unless the student communicates their difficulties to her. Additionally, Blair specified that an indication of understanding takes place when the student can clearly explain procedures in completing a problem, especially when the student is working with her one-on-one. Lastly, Blair described holistically viewing the body of a student's work as a signal for understanding. This includes the time a student is spending on the homework, as well as the types of questions or level of the problems the student is getting incorrect. Blair's answer for this question is centered around students being able to utilize concepts being taught. *(Emerging Constructivist)*.

Due to her remote teaching environment, Blair illustrated two class settings. First, Blair has created pre-recorded lectures that students are supposed to watch prior to class meetings. Blair stated that in the lectures her goal is to develop concepts, understanding, and provide

students with skills to complete the assigned homework. Blair also said she tries to be clear and explicit in these videos and furnish multiple approaches to complete exercises. Second, Blair described the live meetings. During this time, Blair relies upon her teaching experience to discuss common student hang-ups. Furthermore, Blair views student homework before class meetings to check where students are making mistakes, then goes through commonly missed exercises with the class. Blair's class meetings accommodate changes based on student feedback through the homework, yet lectures are still predetermined material. *(Transitional).*

Blair explained that pacing is difficult because all of the objectives need to be covered. However, the remote environment has created a benefit in that students can re-watch the lecture videos, so students have the ability to go back to previous lessons at home. During in-class meetings, Blair leverages the reaction icons that students use over the virtual meetings so students can signal Blair when they are ready to move on. Blair said when the majority of the class has given a reaction that indicates the students have had enough time to attempt the exercise, she feels the students are ready to hear her explanation. Blair also pauses and gives short breaks after an explanation, so students have time to think and can ask questions. Blair's decision to move on is based on student feedback, but the feedback is somewhat limited because the students are only providing reactions with icons. *(Transitional)*.

Blair characterized student learning by stating that she believes it is important for students to gain understanding over procedural memorization. In order to create this understanding, Blair has students complete mini-projects which yield real world application and strengthen connections between concepts and procedures. Blair emphasized it is important that the processes taught in class are grounded to applications because it gives meaning to mathematics. Blair concluded that the key to student learning is understanding concepts instead

of procedural work. In summary, Blair discussed student learning from a perspective of applying mathematical concepts, making connections, and students gaining depth in understanding by interpreting mathematical results. *(Emerging Constructivist)*.

In response to knowing students are learning, Blair explained she does not expect all of the learning to take place in class. During class Blair looks for non-verbal cues, such as students looking focused and actively following along. Blair said that because so much information is delivered in class, she expects a lot of the processing and learning to occur outside of the classroom when students can revisit the material at a slower pace. Blair's response is based on student action in non-verbal cues during content delivery. *(Traditional)*.

In reply to her final thoughts, Blair described creating realistic expectations for her students. Blair explained her goal is to meet the students at the knowledge level the students are at, then work to get students to the level they need to attain. An important method for doing this is the mini-projects that Blair assigns. Blair commented, "mini-projects instead of quizzes give [the students] a different way to show me that they understand what is happening." Next, Blair expressed that the remote environment has been difficult, and she is still working to create a positive setting while meeting the course objectives. Blair concluded, "I feel like I am always learning; I'm always growing, and each semester I do something a little different."

In conclusion, one of Blair's responses was coded as *traditional,* four of her responses were coded as *transitional*, and two responses were coded as *emerging constructivist*. Blair's reply to question seven was coded as *traditional*. Her answers to the first, second, fourth, and fifth questions were coded as *transitional*. Last, her responses to questions three and six were coded as *emerging constructivist*. None of Blair's responses were coded as *instructional* or *experienced constructivist*. Blair's responses to the TBI questions tended toward the center,

closer to the student-centered side of the teacher-centered to student-centered beliefs continuum, because six of the seven TBI responses were in the *transitional* and *emerging constructivist* categories.

Riley's TBI Responses

To maximize learning, Riley explained she puts a lot of thought into the learner's perspective which guides the order that material is presented and any prerequisite skills that may need to be reviewed. Next, Riley focuses on finding ways for her students to interact. These interactions in the remote environment include polling students, employing interactives, and using breakout rooms so students have time to think and converse about math. Riley conveyed that the use of interactives such as sliders on Desmos (online graphing software) create a discovery process for maximizing learning. An integral component of Riley's classroom is student communication that includes discussing concepts and asking questions. Riley's answer focused on student interaction with one another and engagement in the material. *(Emerging Constructivist)*.

Riley asserted that her role as a teacher is multifaceted. She listed many aspects of the role which included encouraging students, setting pacing, fostering student study skills, and conveying the mathematical objectives set for the course. Riley described why each role is important for the success of students. For example, Riley stated that students need help staying on track with assignments and encouragement to get past anxieties often created by math as a subject. Riley's aim is to teach the required objectives while also creating student understanding and building relationships with students. *(Transitional)*.

Riley's explanation for knowing when her students understand a concept started with a discussion about the multiple types of homework that she assigns: homework that is meant to

create student questions and develop deeper understanding of concepts. Next, Riley articulated her constant use of questioning students about the process for solving a problem or the answers to problems during class, especially to create interaction with the students. Riley concluded, "it's lots of communication." Riley's comments focus on students using class content to answer questions and demonstrate knowledge. *(Emerging Constructivist).*

First, Riley acknowledged that objectives for the courses that she teaches are required and set by the department, so she makes sure to target all of those. Next, Riley claimed she frequently browses other instructors' syllabi to ensure that the content she is teaching is similar to her colleagues' content, as well as ascertaining that students are prepared for the next course, especially if the department objectives are vague. Riley also discussed comparing her teaching objectives to those at other colleges, because consistency between similar classes at other colleges is another important factor. Riley's decisions about which topics to teach is guided mainly by her school, what colleagues at her college are teaching, and what content other surrounding colleges teach. *(Traditional)*.

The preset schedule Riley created at the beginning of the semester determines class pace throughout the term. However, Riley also explained she is willing to listen to her students and consider their feedback. Riley clarified, "I do listen to [students]; I won't speed through something if they are not ready." To account for changes of pace, Riley stated that she supplements live class meetings with video recorded examples. If the class does not get through the entire lecture on time, then Riley will send students a video explaining the rest of the material. By sending out videos of examples, Riley is able to answer student questions and review missing pre-requisite skills while maintaining her set schedule. Riley also noted that because of recent remote learning environments, students have different skills; so, it is important

to re-explain concepts and pre-requisite skills. Despite altering pacing in class to accommodate student questions, the dominant aspect for scheduling is Riley's written course schedule. *(Traditional)*.

"I think everybody learns best by doing. You know, the students have to do math," asserted Riley. Riley also said repetition is important, and students need to be told that it is okay to make mistakes; that is part of the learning process. Riley wants her students to actively participate, so she described putting her students in groups to promote math communication among peers. Additionally, Riley provides application problems for the students to work on together during class time. Riley's response targets student discussion of math concepts and working collaboratively to make connections between concepts and application. This method also provides students with opportunities to lead the learning process. *(Experienced Constructivist)*.

Riley responded that student interaction is the primary way she knows students are learning. The main interaction in the virtual classroom is students' responses to instructor posed questions. Riley explained that if she asks her students a question and no one responds then that indicates that students do not have confidence or do not know how to respond. This suggests that more explanation is required. Riley also makes use of anonymous student polling, so students are more willing to answer questions. Riley's answer to how she assesses when students are learning is related to the correctness of student responses and whether or not students are attempting to respond to the instructor's questions. *(Instructional)*.

To summarize final thoughts, Riley described herself as being growth minded. Riley stated, "I am willing to try new things. So, I'm not stuck to 'this is the way we have always done it, and we're always going to do it that way'." Riley commented that she embraces using

technology and encourages her students to use it. She adds that using technology has changed how she asks her students questions on assessments, but questions can be created that still test student understanding. Furthermore, Riley tries to implement real world projects that motivate students to be curious and engages students in the material. This also includes having students work in groups, giving students time to process and think about problems, and also using interactive technology like Desmos. Riley also wants to give students the opportunity to see that math is everywhere. Lastly, Riley concluded that exploration of new teaching methods is fun. Some of the things she has tried really work and other things she has tried she has not used again.

Two of Riley's responses were coded as *traditional*, one of her responses was coded as *instructional*, one response was coded *transitional*, two responses were coded as *emerging constructivist*, and one of her responses was coded as *experienced constructivist*. Riley's answers to questions four and five were coded as *traditional*. Her answer to question seven was coded as *instructional*. Riley's response to question two was coded as *transitional*. Her responses to questions one and three were coded as *emerging constructivist*. Last, her response to question six was coded as *experienced constructivist*. Riley had a least one response coded into each of the six categories of the teacher-centered to student-centered beliefs continuum. Her answers were spread out over the spectrum with one response in the center, three responses on the teacher-centered end, and three responses on the student-centered end.

Taylor's TBI Responses

Taylor remarked that her aim is to provide students with as many materials as possible to help her students succeed. These resources include completed lecture notes, guided notes, and lecture videos that Taylor has created. All of these materials are posted on Taylor's website, so students can access the notes at any time. These materials are also linked to the online course

homework, so students are able to access instructional videos created by Taylor that are linked to homework problems. Taylor's response centered on providing information to students. *(Traditional)*.

Taylor's goal for her role as a teacher is to transfer mathematical knowledge. She explained that although students may not understand everything, when the students leave class, her goal is for students to feel confident in attempting the homework. Taylor strives to build her students' confidence in their own mathematical understanding. Taylor's focus in her role is to foster student self-assurance. *(Instructional).*

To determine if students are understanding, Taylor initially responded that homework status and exam scores are one method. Next, Taylor talked about student questions and student emails. Taylor explained that when students ask questions either at the end of class or via email, then she can gauge understanding. Moreover, when students respond to an email or the provided answer with a comment such as "Oh, that makes sense," there is further indication that learning is occurring. Taylor also noted facial expressions are another way to monitor student understanding during class. Taylor's answer is centered around students reiterating knowledge that was presented in class. *(Instructional)*.

Taylor first explained that a curriculum committee decides what topics the instructors are required to teach and which sections from the chosen textbook the instructors should cover. It is Taylor's first priority to guarantee that the outlined curriculum is covered. Nevertheless, there are still problems and extra topics within those sections that are Taylor's choice to cover. In order to determine which of those extra skills Taylor teaches, she relies on using her own experience to ensure students are prepared for the following math courses that they will complete. In choosing specific problems, Taylor described her thought process which follows

questioning how particular problems that are assigned benefit the student. In summary, Taylor commented that her desire is to pare the objective down to the concepts students need to be successful. Although some of the decision is made by the department, Taylor's prioritization of skills students need for the next course formed the majority of her response. *(Instructional)*.

Taylor said she starts the semester with a schedule that she created for the syllabus and, though it is tentative, for the most part she is able to follow it. Taylor commented that her experience is a major aspect for determining appropriate pacing. Moreover, since Taylor has pre-recorded lectures, Taylor references video length for timing. Taylor adjusts each lecture based on student needs, adding that she will take more time to do extra examples or answer student questions if needed especially since each class has different pre-requisite knowledge. Ultimately, Taylor uses her own experience to determine when to move on and to direct scheduling from the beginning of the semester. *(Traditional)*.

Students learn best by working math problems, according to Taylor. She explained that she reminds students to practice and complete as many problems as the they can. Taylor also emphasizes to her students not to simply read class notes; instead, students should actively practice exercises without assistance of notes and complete practice tests at home to build confidence. Taylor's response centered around student practice after instruction. *(Instructional)*.

Taylor replied that she primarily relies on students' completion of homework as an indicator of learning. According to Taylor, the types of questions students email and the student-instructor communication in an email thread suggest that learning is occurring. Taylor also discussed reviewing problems that multiple students miss after a test has taken place. This way the students still have an opportunity to learn a concept that they misunderstood at the time of the

test. Taylor's reply targets work outside of the classroom and her focus for demonstrations of student learning is on transferring information. *(Traditional)*.

In a discussion of final thoughts, Taylor described her reasons for a direct instruction method in class even though she understands that it is not promoted by current research. Taylor explained that she has received positive feedback about her classes from students. Furthermore, Taylor described that she really enjoys teaching and put a great deal of thought into how her class is organized. Her aim during instruction is to explain problems step-by-step in as much detail as possible. Taylor has applied her experience to pare down the objectives and target concepts students really need to understand. Through her methods, Taylor has had a good success rate with their students which is motivation to continue direct instruction.

Three of Taylor's responses were coded as *traditional*, and four of her responses were coded as *instructional*. Her answers to the first, fifth, and seventh questions were coded as *traditional*. Taylor's responses to the second, third, fourth, and sixth questions were coded as *instructional*. None of Taylor's responses were coded as *transitional*, *emerging constructivist*, or *experienced constructivist*. All seven of Taylor's responses were on the teacher-centered side of the teacher-centered to student-centered beliefs continuum.

Harlow's TBI Responses

Harlow described maximizing student learning by assigning homework that necessitates students asking the instructor questions when they do not understand. Harlow emphasized it is important that students do not mimic examples in a rote manner to perform homework without understanding. In Harlow's description, a central aspect for student learning is that students ask questions and refer to lecture notes. Harlow's response to the question indicates predilection for delivering information in a straightforward manner. *(Traditional)*.

To characterize her role as a teacher, Harlow explained she sees herself as a facilitator. Additionally, Harlow described that she also acts as an encourager and a pacesetter. Harlow clarified that in the virtual classroom she can reach out to students more so than in a strictly online class. Furthermore, she sees herself as a translator of notes and of the textbook. Her intent is to break everything down to basics during her lecture. Harlow's teaching objective is to provide information and encourage students' learning opportunities. *(Instructional)*.

Initially, Harlow responded by stating that absence of student facial expressions in online and virtual environments makes determining student understanding during lecture futile. Instead, Harlow communicated she relies heavily upon homework completion to gauge student understanding. Harlow has set a 75% completion requirement for each assignment before students can move on to the next assignment. Harlow clarified that students must have some understanding in order to complete most of the homework assignment and to move forward. Furthermore, if a student cannot attain the 75% requirement, then the student must ask Harlow questions. Harlow commented that she reiterates to students that they should ask questions several times; students are encouraged to email her and to post questions to the forum on the class website. Harlow's assessment of student understanding targets homework completion which requires the students to replicate knowledge presented in class. *(Instructional)*.

Harlow emphasized that her own learning experiences in business and science courses have heavily influenced the topics she chooses to highlight in her teaching. Harlow explained there are required objectives for instructors to cover, but the depth in which Harlow covers each objective is influenced by her own experience. For example, some of the content Harlow teaches in greater detail is determined by the skills students will need in future business classes such as

marketing coursework. Harlow's decision focuses on her own experience and her own direction for the course. *(Instructional)*.

Harlow asserted that the decision to move on to a new topic is based upon getting through the required curriculum. There are certain objectives the department expects to be taught and that the students need for future math classes. Harlow said,

> We have to get through certain material and as much as I would absolutely love to linger longer because I feel that there's, you know, I always have the feeling that there's a big question mark in the room… I'm really sensitive to that even if I don't see the students. But, I am kind of pushed by the curriculum.

Due to these constraints, Harlow ensures required material is taught, which is the driving factor in class pacing. *(Traditional)*.

After reflecting on some of her own teaching interactions, Harlow summarized, "I assume that students learn best by listening, talking, and interacting with me." Harlow also described providing her students with multiple resources such as other texts and the lecture notes to help them study. Harlow's response centered around her delivery of content and students listening while taking notes on the delivered material. *(Traditional)*.

Harlow responded simply, she knows when students are learning by the fact that students are completing their homework and from when the students are asking questions. She referenced her 75% homework completion requirement as an indicator that the students are learning, because they are achieving a score of 75% or higher on each assignment. Otherwise, the students cannot move forward in their homework, so they cannot skip completing an assignment that they do not understand. Harlow described her expectation that when the students are having difficulties in attaining a score of 75% or higher, they should be communicating with her to get

assistance in their learning. Thus, this is how Harlow gauges learning outside of the classroom. Moreover, class time targets information delivery. *(Traditional)*.

In a discussion of final thoughts, Harlow expressed her concern about using group work and application problems for class instruction. Harlow's preference is for direct instruction because, in her experience, students do not enjoy group work or applications. She noted that many of the students lose focus and seem to wait for class to be over in that type of setting. Harlow concluded that although many of her colleagues use group work and application to teach, it is not something that she herself is enthusiastic about.

Four of Harlow's responses to the TBI questions were coded as *traditional*, and three of her responses were coded as *instructional*. None of Harlow's responses were coded as *transitional*, *emerging constructivist*, or *experienced constructivist*. Harlow's answers for the first, fifth, sixth, and seventh questions were coded as *transitional*. Her answers for the second, third, fourth, and sixth questions were coded as *instructional*. All seven of Harlow's responses were on the teacher-centered side of the teacher-centered to student-centered beliefs spectrum.

Casey's TBI Responses

Casey's classroom time targets student questions. Casey outlined the general plan for his class. First, students to come with a baseline understanding developed by pre-made materials that Casey has created which are uploaded on the course website. Then, during class time, students should be asking questions and getting instructor help on the concepts that they do not understand. Casey emphasized discourse during class meetings which is partially led by student questions. *(Emerging Constructivist)*.

Casey claimed that his main job as a math instructor is to help students understand a variety of techniques to approach math problems. Furthermore, Casey said his primary concern

is teaching students correct math that stresses understanding definitions, theorems, and the application of math concepts. Another aspect to teaching that Casey described is being a guide. He said, “I don’t want to be there to just like mark them off for doing something wrong.” He elaborated that he wants to point out specific errors or common mistakes and provoke students to think about why something is incorrect. Casey does not want the students to feel that his goal is to be strict or merely grade work. Casey’s response to the question demonstrated attention towards building student relationships and understanding. *(Transitional)*.

According to Casey, viewing student work during class time is what shows him the most about student understanding. Casey explained that students are supposed to complete some problems before class, then during class students are invited to ask questions and work through a second set of exercises. Casey often views student work for both the pre-class and post-class problems. Improvements that students make between the two sets of work demonstrates the students’ understanding of the concepts. Additionally, this gives Casey opportunities to see gaps in student knowledge. Casey’s method for checking student understanding is aimed toward students establishing the ability to use concepts that he has presented. *(Instructional)*.

In his response, Casey first explained that for lower-level courses at his college there are set objectives and department outlines for final study guides. So, Casey bases his instruction on the department provided objectives, especially those that appear on the final exam guide. Casey further explained that his course uses a textbook chosen by the department, so he aligns his instruction with the textbook. His primary goal is that students will be able to complete the homework problems. Casey’s instructional goals target the department curriculum and the textbook. *(Traditional)*.

In determining pacing, Casey responded that his lectures are pre-recorded. The length of these lectures was determined based on past experience. Casey described using experience to determine how many examples of each topic to complete in the pre-recorded lectures. Casey fine-tunes lecture notes, so the pre-recorded videos reflect more examples on concepts that prior students had difficulty understanding. Additionally, the videos also discuss examples that highlight common errors to avoid. Next, Casey remarked that, in class, students set the pace. The pace is determined by student questions and student responses to his posed questions. During class meetings, Casey asks students questions throughout the process of working examples at the board. Afterwards, a discussion occurs. Lastly, Casey asks if students have more questions. If there are more questions, further discussion takes place; if there are not, then the class moves on to the next topic. Casey's in-class methods are guided by an ongoing process of assessing student answers and responses. Moreover, students are guiding the pace. *(Experienced Constructivist)*.

Casey explained that to learn mathematics, students should be incorporating several processes. First, they should be introduced to definitions and concepts. Second, student must see examples to which the definitions and concepts are applied along with procedures for solving the examples. Casey described modeling the process of integrating definitions and theorems with procedures to solve problems. Third, students should be practicing the examples and other similar problems. Casey noted that at the beginning of practice students should reference notes, but the students should complete enough examples as to be able to solve problems unassisted. During this practice period students should ask questions and pinpoint areas of confusion. Casey explained that he thinks of this process as a cycle. He added that it is also helpful if students explain mathematics to one another to help each other learn. Casey's idea of student learning

integrates peer-to-peer communication and also follows a process or other guidelines that he models. *(Transitional)*.

Communication and feedback from students are dominant aspects in knowing that students are learning in class, according to Casey. This communication includes direct responses to Casey during class as well as discussions that Casey hears between peers. He also referenced performance on quizzes and tests as an indicator of learning. Casey's response focuses on student interaction with the instructor and with one another. *(Emerging Constructivist)*.

During the discussion of final thoughts, Casey reiterated his belief that it is really important for students to attend office hours and get specialized one-on-one attention. Students have different levels of understanding, so having opportunities to meet with the instructor individually gives students a chance to discuss math with the instructor in a way that applies specifically to the student. Next, Casey explained another goal while teaching is to create an environment where his students feel comfortable asking questions and discussing math. Additionally, Casey said that he puts effort into responding to students in a way that fosters positive communication and encourages other students when they see their peers interacting with one another and the instructor.

One of Casey's responses was coded as *traditional*, one response was coded as *instructional*, two responses were coded as *transitional*, two responses were coded as *emerging constructivist*, and one response was coded as *experienced constructivist*. At least one of Casey's answers was coded into each of the categories on the teacher-centered to student-centered beliefs spectrum. His answer to the fourth question was coded as *traditional*. His answer to the third question was coded as *instructional*. Casey's answers to the second and sixth questions were coded as *transitional*. His answers to the first and seventh questions were coded as *emerging*

constructivist. His answer to question five was coded as *experienced constructivist*. Two of Casey's responses were on the teacher-centered side of the teacher-centered to student-centered teaching beliefs spectrum. Two responses were coded in the center of the spectrum. Three of his responses were coded on the student-centered side of the continuum.

Addison's TBI Responses

Addison's aim for maximizing instruction is to provide students with examples as well as opportunities to complete examples on their own. Addison clarified that during an in person setting he walks around the room and views student work, whereas in the online environment he poses questions to students about each student's solution and how they came to the solution. This creates a class discussion. Addison constructs a classroom where students have opportunities for discussion between times of direct instruction. *(Transitional)*.

Addison characterized his role as a teacher in three main ideas. First, he sees himself as a peer in learning; someone who is there to help by giving one-on-one tutoring. Secondly, Addison described his management role that includes setting deadlines and keeping classroom instruction on an appropriate pace. Lastly, Addison expressed his goal to facilitate learning. This entails keeping students engaged while getting the material across. Addison summarizes two goals: providing students with learning opportunities and oversight of pacing to meet course objectives. *(Instructional)*.

In response to knowing when students understand, Addison described students' facial expressions as an indicator of understanding. Addison also stated, "I can see that little light bulb moment that it clicks." Secondly, Addison explained that there are also the typical quizzes and exams where he tests the students' knowledge. Addison primarily uses assessment as means for checking understanding along with visual cues. *(Instructional)*.

Addison responded that he makes sure that all the department objectives are covered. That is his foremost goal. However, Addison also explained that based on the class culture or even the class engagement that day, extra anecdotal material is added to the lecture or sometimes cut. The purpose of the material is to help students make connections, but there is not always time for those extras. The primary content Addison teaches is guided by the department. *(Traditional)*.

Addison stated he moves on when the required objectives are covered. This mostly entails completing his notes. Addison described that he will go through several examples with the class and give students the opportunity to try exercises and ask questions. Due to prior experience, Addison comments that if he had students struggle with a concept in the past, he will purposely complete more examples with current students before moving on. Furthermore, Addison responds that if the students seem confused and request more examples, he will always find another example to complete before moving forward. Addison's decision to move on is mostly determined by his own direction with some feedback from students. *(Instructional)*.

Addison's answer for how students learn best is straightforward. He asserts that students need to actively participate while in class. Students need to perform the problems, not just listen to the lecture. Addison focuses on students doing the problems which have been discussed and shown in lecture. *(Instructional)*.

Student communication is the primary method for indications of student learning in Addison's opinion. Communication from students includes students responding to instructor posed problems and peer-to-peer discussion when working problems during class. Addison's response targets student interaction with one another and with the instructor. His explanation of the communication is related to worked problems during class. *(Emerging Constructivist)*.

In response to final thoughts on teaching practices, Addison shared that he provides his students with follow-along notes, and he posts video-recordings of his class meetings on his course website. Addison explained that these two extra resources have yielded positive feedback from students and positive results. The follow-along notes have helped students keep up with instruction during class meetings and are a resource to keep students caught up when class is missed. The notes are posted at the beginning of the semester, so students can access the notes at any time. Similarly, the videos have been an aide for students who miss class. Moreover, students can re-watch the videos to study and see examples again. Addison also stated that class attendance is still full, so the videos are an aide and not a replacement for in-person class meetings. Addison summarized that he wishes to provide his students with any extra resources that might help his students be more successful in learning.

One of Addison's responses was coded as *traditional*, four of his responses were coded as *instructional*, one of his responses was coded as *transitional*, and one of his responses was coded as *emerging constructivist*. None of Addison's answers were coded as *experienced constructivist*. Addison's response to the fourth question was coded as *traditional*. His responses to the second, third, fifth, and sixth questions were coded as *instructional*. Addison's response to the first question was coded as *transitional*. His response to the seventh question was coded as *emerging constructivist*. Five out of seven of Addison's responses were coded on the teacher-centered side of the teacher-centered to student-centered teaching beliefs continuum.

Summary of Instructor Responses

The seven TBI questions are aimed at capturing teaching beliefs for their teaching practices, processes of student learning, and assessment of student knowledge. In the TBI the first, second, and fourth questions are about teaching practices. The sixth and seventh questions

are about student learning. Lastly, the third and fifth questions are about assessment of student knowledge.

For question one, about teaching practice, instructor responses varied between *traditional* to *emerging constructivist* codes. In question two, also about teaching practice, instructor responses were coded as either *instructional* or *transitional*. For question three, about assessment, instructor responses were either coded as *traditional*, *instructional*, or *emerging constructivist*. For question four, about teaching practices, instructor responses were either coded as *traditional*, *instructional*, or *transitional*. For question five, about assessment, instructor responses varied with at least one of the instructor's responses being coded into each of the five coding categories in the rubric. For question six, about student learning, instructor responses also varied with at least one instructor's response being coded into each of the five categories in the rubric. For question seven, about student learning, instructor responses were coded as either *traditional*, *instructional*, or *emerging constructivist*. In Table 7 (below) all seven questions are listed for each instructor under the category that the instructors' response was coded.

There were 49 total questions coded on the teacher-centered to student-centered beliefs continuum; that is seven questions for each of the seven instructors. The code category with the most instructor responses was the *instructional* code with 16 of 49 responses coded as *instructional.* The *instructional* code is on the teacher-centered side of the spectrum. However, it is not the most teacher-centered category. The *instructional* code was applied to a response when the instructor is focused on providing students with experiences yet is still based on teacher decisions.

Next, 13 of 49 responses were coded as *traditional*. The *traditional* code is the most teacher-centered of the five codes. It is applied to a response when the instructor is focused on

the transmission of content and structure in class. There were nine of 49 responses coded as *emerging* constructivist, which is on the student-centered side of the continuum but not the most student-centered code. The *emerging constructivist* code is applied to a response when the instructor is focused on collaboration with students, feedback from the students, and the students' knowledge development. Next, eight of the 49 responses were coded using the *transitional* code. The *transitional* code is in the center of the spectrum. It is applied to a response when the instructor is focused on teacher-student relationships and classroom decisions are subjective with regard to student response. Lastly, only two of 49 responses were coded using the *experienced constructivist* code. This is the most student-centered response on the continuum. This code was applied when the instructor was focused on mediating student knowledge or the interactions between students.

Table 7

Codes for Participants Responses by Question Number

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn	3, 4	1, 2, 6		5, 7	
Blair	7		1, 2, 4, 5	3, 6	
Riley	4, 5	7	2	1, 3	6
Taylor	1, 5, 7	2, 3, 4, 6			
Harlow	1, 5, 6, 7	2, 3, 4			
Casey	4	3	2, 6	1, 7	5
Addison	4	2, 3, 5, 6	1	7	

Cross-Case Summary of Teacher Beliefs Interviews

Question 1

1. How do you maximize student learning in your classroom? (Teaching practice)

In the responses to question one, two of the instructor responses were coded as *traditional*, one instructor response was coded as *instructional*, two instructor responses were coded as *transitional*, and two instructor responses were coded as *emerging constructivist*. None of the participants responses were coded as *experienced constructivist*.

Both Harlow and Taylor had responses that were categorized as *traditional*. Harlow's answers and Taylor's answers focused on information delivery. Taylor targets providing information through lecture and other resources provided on her website. Harlow's answer described assigning homework in a way that requires students to ask the instructor questions. In this manner, Harlow is able to deliver information during the lesson and additional instruction if the students are struggling. Finn's response to question one was coded as *instructional*. Finn also discussed information delivery; however, Finn also accounted for student feedback that might redirect or modify the information delivered.

Blair's answers and Addison's answers were coded as *transitional*. Blair and Addison both discussed giving students opportunities to discuss mathematics. Additionally, Blair works to provide opportunities for students to be creative in their solutions to further the students' conceptual knowledge. In order to increase student involvement Addison requires his students to complete examples on their own, then the students must explain what they did.

Riley's responses and Casey's responses were both coded as *emerging constructivist*. Riley and Casey both employ student interaction in their classrooms through student discourse.

Both instructors promote peer-to-peer communication when students are in class, especially while practicing math exercises.

The instructors' responses that were in the same categories did describe a belief in similar practice for their classes. The largest difference between the instructors' responses was the amount of student interaction promoted during class lessons. All of the instructors do use direct instruction some of the time during their classes. A difference arose in whether this was the main way to maximize student learning or if other ideas were incorporated as well.

Instructor responses varied across the teacher-centered to student-centered beliefs continuum. Three instructor responses were on the teacher-centered side, two instructors were in the middle, and two instructors were closer to student-centered (Table 8). However, none of the instructor responses were coded as *experienced constructivist* which is the most student-centered descriptor of the five codes.

Table 8

Codes for Responses to Question 1

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn		*			
Blair			*		
Riley				*	
Taylor	*				
Harlow	*				
Casey				*	
Addison			*		

Question 2

2. How do you describe your role as a teacher? (Teaching practice)

For question two of the interview, four of the instructor answers were coded as *instructional* and three instructor responses were coded as *transitional*. None of the responses for question two were coded as *traditional*, *emerging constructivist*, or *experienced constructivist*.

Each of Finn, Taylor, Harlow, and Addison's responses were coded as *instructional*, whereas Blair, Riley, and Casey's responses were coded as *transitional*. All four instructors whose responses were *instructional* provided explanations that centered around information delivery, but each instructor also discussed trying to positively impact the student experience. For example, Finn discussed guiding students by providing more examples or greater details based on student questions. Taylor discussed efforts to build student confidence. Harlow explained that she encourages students and reaches out to students through email. Addison described a goal to keep students engaged and to try to work with students from the perspective of a peer.

For the other three instructors whose responses were coded as *transitional*, each instructor described their role as a teacher as building teacher-student relationships and engaging students in the learning process. In particular, Blair said, "I don't expect my students to copy me and, like, be robotic… I am here to let them know they can do it and try to encourage them throughout the process." Similarly, Riley explained that she wants to help keep students on track, especially by showing empathy when students make a mistake or miss a deadline. She described that so many students are quick to think that math is hard, so she strives to help them change that mindset and boost her students' confidence in their math ability. Casey also described fostering

student relationships in stating that his goal is to make students think. He stated that he wanted to guide his students and give them a variety of tools for understanding mathematics.

The main difference between the instructors in the *instructional* category versus those in the *transitional* category is a distinction between trying to engage students during direct instruction or trying to build a relationship with the students during learning opportunities outside of direct instruction. Finn, Taylor, Harlow, and Addison all showed this in their conversations in how they each discussed trying to help students through their lectures and class discussions. Conversely, Blair, Riley, and Casey all demonstrated ways that they focus on promoting student habits first, even if it means giving up some time for direct instruction.

All of the instructor responses for question two were slightly teacher-centered or in the middle of the teacher-centered to student-centered beliefs continuum (Table 9). None of the instructors were at the very end of the teacher-centered side of the continuum. Furthermore, none of the instructor responses were coded into the student-centered side of the spectrum.

Table 9

Codes for Responses to Question 2

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn		*			
Blair			*		
Riley			*		
Taylor		*			
Harlow		*			
Casey			*		
Addison		*			

Question 3

3. How do you know when your students understand? (Assessment)

In question three, one instructor response was coded as *traditional*, four instructor responses were coded as *instructional*, and two as *emerging constructivist*. Finn's response was coded as *traditional*. His response for student understanding focused on students receiving information.

Taylor, Harlow, Casey, and Addison all supplied answers that were coded as *instructional*. All four instructors' responses implied that they know students understand when the students can repeat exercises learned in class. For instance, Taylor centered her explanation around students' exam and homework performance. Likewise, Harlow relies on students' homework as an indication of student understanding. Casey also checks for understanding using tests as well as exercise completion. Addison discussed testing, but also talked about facial expressions.

Both Blair's and Riley's explanations were coded as *emerging constructivist*. Both instructors described methods that emphasized checking for student understanding through student interaction and communication. Additionally, both instructors look for ways that their students can show understanding that does not require repetition of examples. In contrast to the other five instructors, Blair and Riley both provide students with chances to demonstrate understanding in multiple ways.

In response to question three, one of the instructor responses was coded on the teacher-centered side of the continuum of teacher-centered to student-centered beliefs (Table 10). Four other instructors were one step closer to student-centered, yet primarily teacher-centered. None of the instructors' responses were in the middle of the continuum. Lastly, two of the instructors'

responses were a step closer to the student-centered side of the continuum, but none of the instructor responses were coded at the student-centered end.

Table 10

Codes for Responses to Question 3

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn	*				
Blair				*	
Riley				*	
Taylor		*			
Harlow		*			
Casey		*			
Addison		*			

Question 4

4. In the [class] setting, how do you decide what to teach and what not to teach? (Teaching practice)

In question four of the interview, four of the instructor responses were coded as *traditional*, two instructor responses were coded as *instructional*, and one of the instructor response was coded as *transitional*.

Finn, Riley, Casey, and Addison all answered with *traditional* responses. In each of their responses, all four instructors indicated that they relied heavily upon the department required teaching objectives to determine what to teach and what not to teach. These *traditionally* coded instructors each discussed similar aspects, such as department course outlines and objectives, alignment with colleagues, department chosen textbooks, and departmentally issued final study

guides. All seven instructors teach in a math department that mandates a set of objectives for most 100 level math classes; this includes course objectives for the 100 level math classes that were considered in this study.

However, Taylor, Harlow, and Blair make decisions in what to teach based on other factors, while adhering to department requirements as a secondary factor. Taylor's responses and Harlow's responses were coded as *instructional*. Both of the instructors discussed how their experiences as instructors have largely influenced what they choose to teach. Additionally, both instructors explained their desires to prepare students for future classes. Harlow noted that preparing students for applications in business and science was important to her, while Taylor shared preparing students for future math courses as important. Both Harlow and Taylor did make comments about the department required curriculum, but it was not primarily discussed as the main factor for what to teach and how to teach.

Lastly, Blair's response was coded as *transitional*. Like the other six instructors, Blair discussed meeting the department required teaching objectives. She explained that she uses her pre-recorded lecture videos to cover the course objectives that are required by the math department. However, in her class meetings, Blair decides what to teach and what not to teach through student feedback. She explained that she works problems with the class that many of the students answer incorrectly while completing the homework. She discusses the hang-ups that her students are having and gives them opportunities to try these problems again under guidance.

In response to question four of the interview, four of the instructor responses were on the teacher-centered end of the teacher-centered to student-centered beliefs continuum (Table 11). Three of the instructors were one step closer to the middle of the spectrum but were still

primarily teacher-centered. One of the instructor responses was in the middle of the continuum. None of the instructor responses moved toward the student-centered end of the spectrum.

Table 11

Codes for Responses to Question 4

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn	*				
Blair			*		
Riley	*				
Taylor		*			
Harlow		*			
Casey	*				
Addison	*				

Question 5

5. How do you decide when to move on to a new topic in your [course]? (Assessment)

In their responses to question five of the interview, three of the instructor answers were coded as *traditional*, one instructor response was coded as *instructional*, one instructor response was coded as *transitional*, one instructor response was coded as *emerging constructivist*, and one instructor response was coded as *experienced constructivist*. There was more variety in instructor responses to question five compared to the first four questions.

Riley, Taylor, and Harlow each had answers that were coded as *traditional*. All three instructors' answers to question five indicated that moving on to a new topic in the course was directed by the instructor themselves. Both Riley and Taylor referenced following their schedule created prior to the start of the semester as their guide. Taylor explained that her schedule was

tentative, but she is able to follow it closely and rarely has to adjust. Riley explained that she sticks to her schedule. However, she does account for student feedback and adjusts lectures during class based on questioning and conversations led by the students. Nevertheless, Riley manages to adhere to her schedule by sending out videos (recorded after class) to her students that covers any material that she was not able to get through during the allotted class time. In this way, Riley still directs the overall pacing of her instruction. Harlow also directs the pacing of her class. She did not reference her schedule, but she did explain that she was forced to direct pacing by the course objectives. Her main goal is to make sure that all of the content is covered for her course, so she is "pushed by the curriculum" in her decision of when to move forward.

Addison's response was coded as *instructional*. Addison also described following his schedule as a main factor for determining when to move on. Yet, his response was coded as *instructional* because he does account for student feedback. If students are struggling to understand a concept, he will take more class time to go through extra examples and answer student questions. Addison also indicated that he will always do more examples with the class if it is requested by a student. Although schedule is a primary factor, he makes concessions for student requests.

Blair's response was coded as *transitional*. Blair also commented that it is important to ensure that all of the objectives are covered. However, Blair has pre-recorded lecture videos that students can watch at their own pace. This allows Blair to go through topics with the students during class meetings at a pace the students guide. Albeit, this interaction is limited because students indicate when to move on by using the virtual environment reaction icons. So, Blair does changes topics based on student feedback, but feedback from the students is mainly limited to using a thumbs up or a smiling face (or any of the emoticons) which simply means they are

ready. Otherwise, Blair explained that she encourages her students to use their microphone or the chat box to communicate questions at any time during the lecture.

Finn's answer for question five was coded as *emerging constructivist*. Similar to the instructors discussed above, he did mention his tentative schedule. Where Finn's response differs from the other instructors' responses in that he made it clear that his goal was to never move forward until he felt that the core concepts were covered in enough detail to answer all student questions. Furthermore, Finn expressed his wish that students have every opportunity to ask their questions before he moves on to a new topic. He also asks for any student questions at the beginning of each class to ensure that students are confident in the prior concepts before starting the next ones.

Lastly, Casey's reply was coded as *experienced constructivist*. Casey's response was different from the other instructors' responses because his class pacing is tentative and guided almost completely by the students. In order to make this possible, Casey has created a flipped classroom. His students watch pre-recorded lectures at home where they can take notes following the outlines that Casey provides. Students can re-watch and pause the videos as needed while they are learning. Then, during class, Casey has a generalized plan for the class, but overall, Casey lets student interaction determine the pace and the details of the content. Casey stated, "I don't run out of time in class like I used to, so I am able to just get through all of it at the pace that the students mostly set."

In question five, three of the instructor responses were at the teacher-centered end of the teacher-centered to student-centered continuum of beliefs (Table 12). One instructor answer was one step closer to the middle, but still primarily teacher-centered. One instructor response was in the middle of the spectrum. One instructor response was a step closer to the student-centered side

of the spectrum. Lastly, one instructor response was at the student-centered side of the continuum.

Table 12

Codes for Responses to Question 5

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn				*	
Blair			*		
Riley	*				
Taylor	*				
Harlow	*				
Casey					*
Addison		*			

Question 6

6. How do your students learn [mathematics] best? (Student learning)

In their replies to question six, one instructor response was coded as *traditional*, three instructor responses were coded as *instructional*, one instructor response was coded as *transitional*, one as *emerging constructivist*, and one as *experienced constructivist*. Like question five, question six responses varied more than the responses in the first four questions.

Harlow's response was coded as *traditional*. Harlow indicated that she believes her students learn best by listening to her. They should be focused during the lesson and taking notes. Her goal to help students learn best is to translate the textbook into lecture and provide the students with resources.

Next, Finn, Taylor, and Addison all replied with answers that were coded as *instructional*. Both Taylor and Addison explained that they believe the students need to actively completely problems. Likewise, Finn's response indicated that students should be practicing and asking questions during class. All three answers showed that the instructors expected students to reproduce the same type of work that they discussed as a class.

Casey's answer was coded as *transitional*. Similar to the three instructors above, Casey indicated that his students should be practicing the problems themselves. In addition, Casey also explained that his students should be referencing definitions and math theorems to work through problems. He described that students should be using their knowledge of concepts to complete problems. Moreover, Casey said that students should interact with one another to complete problems.

Blair's response was coded as *emerging constructivist*. Blair's answer included similar factors of students practicing and repetition of problems. In contrast to the previous instructors, Blair discussed the importance of understanding concepts versus just repeating procedural steps. She also discussed that it is important for her students to make connections. For those reasons, Blair has implemented mini-projects which give students an opportunity to apply their math knowledge to the real world.

Lastly, Riley's response was coded as *experienced constructivist.* She also indicated that students should be doing math actively. Like Blair, she goes beyond the other instructor responses by giving her students chances to apply what they are learning to real world applications. Furthermore, Riley wants her students to discuss and communicate about math. So, she provides class time where the students can interact in groups and work together.

In question six, one instructor response was on the teacher-centered side of the teacher-centered to student-centered beliefs continuum (Table 13). Three of the instructors supplied responses that were one step closer to the center of the spectrum, but their answers were mostly teacher-centered. One instructor response was in the middle of the spectrum between teacher-centered and student-centered. One instructor response was a step closer to the student-centered end of the continuum. Lastly, one instructor response was at the student-centered side of the spectrum.

Table 13

Codes for Responses to Question 6

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn		*			
Blair				*	
Riley					*
Taylor		*			
Harlow	*				
Casey			*		
Addison		*			

Question 7

7. How do you know when learning is occurring in your [class]? (Student learning)

In their responses to question seven, three of the instructor answers were coded as *traditional*, one instructor response was coded as *instructional*, and three instructor responses were coded as *emerging constructivist*. In this case, the responses seem to be grouped either in a teacher-focused manner or grouped in a student-focused manner.

Blair, Taylor, and Harlow all gave answers that were coded as *transitional*. Taylor and Harlow both expressed that they know when learning is occurring based on their students' completion of the assigned homework. Blair described students being focused during the lesson as an indication of learning. She also discussed that a lot of learning probably happens outside of class. All three instructors provided responses that indicated that learning occurs outside of class and that they use assignments to gauge learning. In this way, answers showed that classroom time is more for information and content delivery.

Riley's response was coded as *instructional*. She explained that she relies on student interaction with the instructor as a gauge of student learning during class. She uses posed questions in lecture to check that learning is occurring. Riley also added that silence from students is a bad thing.

Finn, Casey, and Addison each responded with answers coded as *emerging constructivist*. Both Casey and Addison explained that a main indicator of learning occurs when students interact with one another, especially when they hear students explaining the problem or concept correctly to a peer. Finn explained that the main signal he uses to check learning is the type of questions that students ask. He elaborates that if students ask a question related to an application of the concept or if they ask a question that ties directly into the next concept the class is discussing, then he knows that learning is occurring. All three instructors supplied answers that showed they rely on students' interactions with the content in ways that show they are applying the concepts being taught.

In question seven, three of the instructor responses were on the teacher-centered end of the teacher-centered to student-centered continuum of beliefs (Table 14). One instructor was one step closer to the middle of the spectrum, but mostly still teacher-centered. Three of the

instructors were one step closer to the student-centered end of the spectrum but were not entirely student-centered in their responses. None of the instructor responses were in the middle of the continuum, nor were any responses at the end of the continuum on the student-centered side.

Table 14

Codes for Responses to Question 7

Participants	Traditional	Instructional	Transitional	Emerging constructivist	Experienced constructivist
Finn				*	
Blair	*				
Riley		*			
Taylor	*				
Harlow	*				
Casey				*	
Addison				*	

Instructor Observations

The Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013) has been used for observations in the university setting. Utilizing this instrument, the researcher circled any code that was observed in a five-minute interval. This was repeated every five minutes for the duration of each class that was observed. Since the intervals were five minutes long, several behaviors, interactions, and technologies could be observed simultaneously or consecutively within the same five-minute interval. However, a coded behavior did not have to occur for the entire interval to be circled.

There are three observation categories of the TDOP. They are Teaching Methods, Cognitive Engagement, and Instructional Technology. The Teaching Methods category identifies

the instructor's action at the moment it was observed. The Cognitive Engagement category identifies student behavior and interaction during the same interval. Lastly, the Instructional Technology category identifies instructional tools utilized in that observation interval. The codes on the TDOP are provided in Table 15 below. There are 30 codes that were used as part of the TDOP. Each category of the TDOP had a varying number of codes: 15 of the codes were behaviors for Teaching Methods, five of the codes were behaviors for Cognitive Engagement, and 10 of the codes identified tools for Instructional Technology.

Table 15

Teaching Dimensions Observation Protocol Codes for Observed Behaviors

Observed Behavior	Example
Teaching Methods	
Lecture (LEC)	Instructor verbally presents factors or concepts
Multimedia (MM)	Instructor uses more than one medium of expression or communication
Illustration (IL)	Instructor uses a story or anecdote to describe a fact or concept
Demonstration (DEM)	Instructor demonstrates use of interactive software or video clips
Worked out problems (WP)	Instructor engages in the active solving of numerical problems
Small-group work (SGW)	Instructor directs students to work in pairs or small groups
Desk work (DW)	Instructor directs students to work alone at their desks
Case study (CS)	Instructor presents a case for detailed elaboration and analysis
Online techniques (OT)	Instructor actively draws on the course website
Rhetorical question (RQ)	Instructor poses a question as a figure of speech for illustrative or persuasive reasons
Display conceptual question (DCQ)	Instructor poses a question to obtain information about student comprehension about concepts
Display algorithmic question (DAQ)	Instructor poses a question to obtain information about student comprehension about algorithms or computations
Comprehension question (CQ)	Instructor poses a question to assess students' generalized understanding of a previous topic
Novel question (NQ)	Instructor poses a question to which he or she does not know the answer
Whole-class discussion (CD)	Instructor and students engage in back-and-forth discussion
Cognitive Engagement	
Receive/memorize information (RM)	Students hear facts and information with expectations only that they will internalize and recall information
Understanding problem solving (PS)	Students follow solution paths or other analytic processes
Creating ideas (CR)	Students engage in brainstorming activity at their desks and report back to the class with their ideas
Integrating ideas (IN)	Students actively reflect on prior knowledge and its relationship to new information
Connecting to the real world (CN)	Students relate course material to common experiences or aspects of their daily lives
Instructional Technology	
Demonstration equipment (D)	The instructor walks through calculator use
Computer and slides (LC)	A computer connected to a digital projector that displays slides on a screen
Posters (PO)	Posters on the wall
Book (B)	A textbook or other book physically used by the instructor
Pointers (P)	Laser pointers used to shine a focused light on a screen or a physical pointer to indicate writing on a board or screen
Clicker response systems (CL)	Handheld devices with which students indicate answers to multiple-choice questions projected onto a screen
Overhead Projector/Elmo (OP)	A projector that displays images or writing on transparent sheets or plastic
Digital Tablet (T)	A computer that displays images or writing directly onto a screen
Blackboard/Whiteboard (BB)	A blackboard or whiteboard hung on walls at the front of a classroom
Miscellaneous object (OB)	A miscellaneous instructional artifact not captured by other codes

Note. Adapted from "Instructional Systems of Practice: A Multidimensional Analysis of Math and Science Undergraduate Course Planning and Classroom Teaching," by M. T. Hora and J. J. Ferrare, 2013, *Journal of the Learning Sciences, 22,* p. 225-227. (https://doi.org/10.1080/10508406.2012.729767)

It should be noted that some of the codes in the TDOP have similarities, but there are small differences between them. *Demonstration* is listed as a Teaching Method and *Demonstration Equipment* is a code for Instructional Technology. In this case, *Demonstration* was specifically coded when the instructor presented an interactive software or video clip that had some type of live action, whereas *Demonstration Equipment* was specifically coded when an instructor showed students how to use calculators or other technology to generate graphs or tables. *Computer and Slides* and *Digital Tablet* were two similar Instructional Technology codes. *Computer and Slides* was coded when an instructor displayed slides of information that had been prepared to display prior to class. *Digital Tablet* was coded when an instructor actively wrote notes using a digital device where students could see the writing occurring in real time. Sometimes *Computer and Slides* and *Digital Tablet* were coded at the same time if the instructor was writing on pre-made computer slides and adding more notes or examples in real time.

Display Conceptual Question, *Display Algorithmic Question*, and *Comprehension Question* are codes in the Teaching Methods category that have subtle differences. *Display Conceptual Question* was coded when an instructor posed a question about the current class topic to gauge the students' understanding of a new concept being taught. This code was typically used when instructors checked that students were following along with the lesson and to check that students did not have any questions at that time. *Display Algorithmic Question* was coded when an instructor posed a question about an algorithmic or procedural process. This code was typically applied when instructors asked the class what the next mathematical step was in completing worked problems. *Comprehension Question* was coded when an instructor asked a question to identify students' pre-requisite knowledge. This code was typically applied when

instructors asked about concepts that the students should understand in order to move forward with the current concept.

Each instructor's course was observed three times, except for Blair; her course was observed four times. The six other instructors were scheduled for three observations, each being 75-80 minutes long. Blair's courses had split schedule times, so one class was observed for its 75-minute duration and the other three classes were observed for their 50-minute durations. This allowed the researcher to schedule 225-240 minutes of observation time for each instructor. The following paragraphs summarize the instructor observations. Additionally, frequency tables are provided for each instructor. The tables are the relative frequency of each TDOP behavior code for the total observation time which varied by instructor.

Finn's Observation Summary

Finn's in-person classes were observed three times. The total time spent observing Finn was 210 minutes. So, relative frequencies were calculated based on a total of 42 intervals of five minutes. Finn ended two observation classes early. The relative frequency of Finn's behaviors that were observed using the TDOP are shown in Table 16. Codes from the TDOP that Finn did not exhibit during the observations were removed from the table.

Finn lectured during some part of every interval, so his relative frequency for *lecturing* was 1.00. Since Finn typically wrote notes while speaking, his relative frequency for *multimedia* was 0.98. The other Teaching Method behaviors that had a high frequency were *working out problems* (relative frequency 0.81) and instructor posed *comprehension questions* (relative frequency 0.83). The most frequent student behavior for Cognitive Engagement was students *receiving/memorizing information* (relative frequency 0.83). Lastly, Finn used the overhead

projector and document camera throughout his classes, so the *overhead projector/Elmo* code had the highest relative frequency (0.98) in the Instructional Technology category.

There were 11 behaviors from the TDOP that Finn did not manifest. In the Teaching Methods category, Finn did not exhibit the following teaching practices: *demonstrations*, *small-group work*, *case studies*, or *novel questions*. In the Cognitive Engagement category, Finn did not engage the students in *creating ideas*. Lastly, in the Instructional Technology category Finn did not utilize the following tools: *posters*, *blackboard/whiteboard*, *books*, *miscellaneous objects*, *clicker response systems*, or a *digital tablet*.

Table 16

Relative Frequency of Observed Teaching Practices- Finn

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	1.00	Receive/memorize Information	0.83	Overhead Projector/Elmo	0.98
Multimedia	0.98	Understanding Problem Solving	0.74	Pointers	0.69
Comprehension Question	0.83	Connecting to the Real World	0.57	Demonstration Equipment	0.57
Worked Out Problems	0.81	Integrating Ideas	0.24	Computer and Slides	0.05
Display Conceptual Questions	0.55				
Display Algorithmic Questions	0.52				
Whole-class Discussion	0.45				
Illustration	0.31				
Rhetorical Question	0.26				
Online Techniques	0.12				
Desk Work	0.12				

Finn typically used the classroom projector and the document camera. He wrote class notes on sheets of blank white paper under the document camera and used colors when writing to emphasize concepts or clarify work. Finn began each class with announcements about upcoming homework, large projects, and upcoming test dates. Moreover, he asked students if they wished to go over any problems or had any questions about the material from the prior class or homework.

As part of the class notes, Finn wrote out definitions and theorems while he explained them. He also wrote out procedural steps and algorithmic phrases. When explaining more about a written theorem or definition, Finn walked around the room and reindicated main concepts with hand gestures. While teaching, Finn encouraged students to follow along with the examples. Sometimes he asked students to try an example on their own at their desks. After students had an opportunity to work through the problem, Finn asked the class questions creating a class discussion and facilitating student interactions. If Finn asked a basic comprehension question, he waited for the entire class to respond before moving on. Furthermore, Finn used phrases such as "good job" or "excellent question" to encourage students to ask questions or answer his posed questions. After each example, Finn provided wait-time so students could take time to process and ask additional questions. Finn repeated main concepts throughout the class period and showed multiple methods for solving problems.

The third class that was observed had a slight change in structure from the first and second classes that were observed. Finn demonstrated how to use statistics software to generate different types of graphs, tables, and histograms. He verbally explained the steps while writing them out; then, he showed the process step by step on his computer which was projected for the students to see. He also encouraged the students to follow along on their own computers.

Blair's Observation Summary

Blair's virtual classes were observed four times. The total time spent observing Blair was 220 minutes. So, relative frequencies were calculated based on 44 intervals of five minutes. The first, second, and fourth classes were 50 minutes long and the third class was 70 minutes long. The relative frequencies over the 44 intervals are provided in Table 17. Any of the TDOP behaviors that Blair did not exhibit were removed from the table.

Blair provided students with direct instruction during some portion of almost all of the five-minute intervals, so her relative frequency for *lecture* was 0.98. This was the highest occurring code in the Teaching Methods category. Blair's *multimedia* relative frequency was 0.78, indicating that she wrote down notes as she discussed topics. Blair also provided her students time to work each problem before she discussed them, so her relative frequency for *worked out problems* and *desk work* were both 0.69. The most frequent code in the Cognitive Engagement category was *receive/memorize information* (relative frequency 0.98). Students were also engaged in *connecting to the real world* for 73% of the coding intervals and *understanding problem solving* 67% of the coding intervals. The Instructional Technology that Blair utilized the most was *computer and slides* (relative frequency 0.89) and her *digital tablet* (relative frequency 0.78). Blair used a *miscellaneous object* (relative frequency 0.56). This object included her students using the reaction icons (such as the smiling face or the thumbs-up emoticon) in the virtual classroom environment.

There were 11 behaviors that Blair did not exhibit on the TDOP. In the Teaching Methods category Blair did not perform the following practices: *small-group work*, *case studies*, *rhetorical questions*, *display conceptual questions*, *display algorithmic questions*, or *novel questions*. In the Cognitive Engagement category Blair did not have students *creating ideas*. In

the Instructional Technology category Blair did not utilize *posters*, *blackboard/whiteboard*, *books*, or the *overhead projector/Elmo*.

Table 17

Relative Frequency of Observed Teaching Practices- Blair

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	0.98	Receive/memorize Information	0.98	Computer and Slides	0.89
Multimedia	0.78	Connecting to the Real World	0.73	Digital Tablet	0.78
Desk Work	0.69	Understanding Problem Solving	0.67	Miscellaneous Object	0.56
Worked Out Problems	0.69	Integrating Ideas	0.16	Demonstration Equipment	0.13
Whole-class Discussion	0.49			Clicker Response System	0.09
Comprehension Question	0.33			Pointers	0.07
Illustration	0.29				
Online Techniques	0.09				
Demonstration	0.04				

Since Blair's class was in a virtual setting, she had her camera on so students could see her as she was teaching. Students did not typically have their cameras on. They also usually had their microphones muted. They were encouraged to unmute and speak up at any point they did have questions. Blair screen-shared pre-made slides with her students from her computer and her digital tablet so she could write on the slides.

Blair started each class with a warm-up question for the students to answer using the virtual chat feature. The warm-up question in each observation was a non-math question. Next,

Blair discussed class announcements and reminders. During the third observation, these announcements included recommendations for test preparation and a walk-through on the instructor website in which Blair showed the students where to find extra test preparation material. Since Blair had pre-made lecture videos, her design for the virtual meetings was to complete chapter reviews. This entailed a short summary of big ideas where the students listened to the summary and were welcome to ask questions.

After finishing the summary, Blair presented problems for her students to complete. She provided them work time to do each problem on their own. When the students were done with the problem, they indicated that they were ready for her explanation by using one of the video chat reaction icons. Once a majority of students had indicated that they had completed the problem, Blair provided the class with a step-by-step explanation for completing the problem. This process was repeated for the duration of the classes. Throughout the class, Blair encouraged students to ask questions either using the chat feature or their microphones.

Riley's Observation Summary

Riley's virtual classes were observed three times. The total time spent observing Riley was 240 minutes. So, relative frequencies were calculated using 48 intervals of five minutes. The relative frequency of Riley's behaviors that were coded on the TDOP are shown in Table 18. Any codes on the TDOP that Riley did not exhibit have been removed from the table.

The most frequently occurring code in the Teaching Methods category for Riley was *lecture*, which she did for some portion of every interval, so the relative frequency is 1.00. During most of the intervals in which Riley was providing direct instruction she also wrote down notes, so *multimedia* was coded with a relative frequency of 0.94. The other high occurring teaching behaviors were *whole-class discussions* (relative frequency 0.77) and *working out*

problems (relative frequency 0.75). In the Cognitive Engagement category, the most frequent student behavior was *receiving/memorizing information* which occurred during some portion of every interval (relative frequency 1.00). There was also a high occurrence of *understanding problem solving* (relative frequency 0.71). In the Instructional Technology category, Riley utilized *computer and slides* during every interval (relative frequency 1.00). She also wrote on the slides digitally in real time, so the *digital tablet* code had a relative frequency of 0.92. Riley utilized a digital tool that allowed students to draw on her premade slides in the virtual meet; this was coded as *miscellaneous object* (relative frequency 0.10).

There were seven behaviors from the TDOP that Riley did not exhibit. In the Teaching Methods category, Riley did not complete *demonstrations* or *small-group work*. In the Cognitive Engagement category, Riley did not have students *create ideas*. Lastly, in the Instructional Technology category, Riley did not use *posters*, the *blackboard/whiteboard*, *clicker response systems*, or an *overhead projector/Elmo*.

Table 18

Relative Frequency of Observed Teaching Practices- Riley

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	1.00	Receive/memorize Information	1.00	Computer and Slides	1.00
Multimedia	0.94	Understanding Problem Solving	0.71	Digital Tablet	0.92
Whole-Class Discussion	0.77	Integrating Ideas	0.48	Pointers	0.29
Worked Out Problems	0.75	Connecting to the Real World	0.13	Demonstration Equipment	0.21
Comprehension Question	0.44			Miscellaneous Object	0.10
Display Algorithmic Questions	0.42			Book	0.02
Rhetorical Question	0.31				
Display Conceptual Questions	0.29				
Illustration	0.17				
Online Techniques	0.13				
Desk Work	0.10				
Case Study	0.04				
Novel Question	0.02				

Riley's class was in a virtual setting. Riley shared her screen during the virtual meeting, so students could see her prepared slides. Although the slides were premade with content, the slides were created with blank spaces so they could be written on and added to during class. Riley added to the notes and wrote out all of the mathematical steps for the examples during class. While writing on the slides, she used different colors, highlighters, and a digital pointer to emphasize ideas.

Riley began each class with announcements such as homework reminders, quiz reminders, and feedback on recently graded assignments. While making the announcements, Riley navigated through her course website, showing students where to find assignments. She also displayed the course calendar of due dates. During instruction, Riley encouraged students to actively participate by asking questions and by creating interaction in the chat. Riley provided wait time for students to ask questions and for students to write down formulas.

Riley used the following features to create engagement in her class. First, she introduced concepts using famous people and real-world applications. Second, she used Desmos (an internet graphing application with computational abilities) to have students manipulate the graphs of trigonometric functions. Third, students could write on the class slides when Riley unlocked the writing feature for them. This allowed Riley the ability to let students show their ideas before she discussed solutions to the examples. Fourth, Riley encouraged discussion. These discussions included connecting old concepts to new ones, relevance to applications, and explanations of thought processes while working problems.

Taylor's Observation Summary

Taylor's in-person classes were observed three times. The total time spent observing Taylor was 220 minutes. So, relative frequencies were calculated using 44 intervals of five minutes. The relative frequencies of Taylor's behaviors from the TDOP are shown in Table 19. The TDOP code behaviors that Taylor did not exhibit have been removed from the table.

In the Teaching Methods category, Taylor's most frequent behavior was *lecture* (relative frequency 1.00) which occurred during most of each interval for all of the observation intervals. Similarly, *multimedia* had a high relative frequency of 0.98 because Taylor wrote on the board while discussing concepts. During every interval, Taylor *worked out problems* (relative

frequency 0.98). In the Cognitive Engagement category, students were most frequently *receiving/memorizing information* (relative frequency 1.00). Lastly, in the Instructional Technology category, Taylor utilized the *blackboard/whiteboard* during instruction, so the relative frequency was 1.00. She also frequently used gestures and *pointers* (relative frequency 0.80) to emphasize key points.

There were 19 behaviors from the TDOP that Taylor did not manifest. In the Teaching Methods category, Taylor did not complete any *demonstrations*, *small-group work*, *case studies*, *online techniques*, *whole-class discussions*, *display conceptual questions*, *display algorithmic questions*, *comprehension questions*, *novel questions*, or *desk work*. In the Cognitive Engagement category, Taylor did not have the students *understanding problem solving* or *creating ideas*. In the Instructional Technology category, Taylor did not utilize *posters*, *computer and slides*, *clicker response systems*, *books*, the *overhead projector/Elmo*, *miscellaneous objects*, or a *digital tablet*.

Table 19

Relative Frequency of Observed Teaching Practices- Taylor

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	1.00	Receive/memorize Information	1.00	Blackboard/ Whiteboard	1.00
Multimedia	0.98	Integrating Ideas	0.36	Pointers	0.80
Worked Out Problems	0.98	Connecting to the Real World	0.09	Demonstration Equipment	0.05
Rhetorical Question	0.07				
Illustration	0.02				

Since Taylor's class was in person, Taylor provided direct instruction using the whiteboard. Taylor started each class by providing any relevant announcements about upcoming tests and assignments. Taylor also reminded the students that they could print all of the lesson notes that she explained during class from the class website at any time. Then, Taylor began instruction by picking up where the last lesson had left off. Taylor used black markers for writing the notes and working problem examples.

In Taylor's lesson she explained main concepts, then worked several example problems to demonstrate the concepts. Taylor was detailed in her work for the example problems, writing out each step and showing most of the arithmetic on the board. She also added in personal recommendations for students to use on the homework and described common errors that the students should avoid making. After finishing an example, Taylor reiterated the main concepts in the example before moving on to the next one.

Most pauses in instruction took place when Taylor erased the board. Students could raise their hand and ask questions at any point in the lecture. Taylor did not ask the class any questions during the observations. However, Taylor did end class a few minutes early each class so students could stay afterward to individually ask her questions. During the last observation, Taylor spent the class period going over review problems for the test that would take place the following class.

Harlow's Observation Summary

Harlow's virtual class was observed three times. The total time spent observing Harlow was 240 minutes. So, relative frequencies were calculated using 48 intervals of five minutes. The relative frequencies of Harlow's behaviors from the TDOP are shown in Table 20. The behaviors in the TDOP that Harlow did not exhibit have been removed from the table.

In the Teaching Methods category Harlow's most frequent behavior was *lecture* (relative frequency 1.00). Harlow wrote out notes while providing instruction, so *multimedia* (relative frequency 0.89) was also coded for most of the intervals. In the Cognitive Engagement category students were *receiving/memorizing information* for some portion of every interval (relative frequency 1.00). Lastly, in the Instructional Technology category, Harlow utilized her *digital tablet* to screen-share and write notes (relative frequency 0.89).

There were 12 behaviors from the TDOP that Harlow did not manifest. In the Teaching Methods category, Harlow did not exhibit *demonstrations*, *small-group work*, *case studies*, or *novel questions*. In the Cognitive Engagement category, Harlow did not have students *connect to the real world*. Lastly, in the Instructional Technology category, Harlow did not use *posters*, the *blackboard/whiteboard*, *clicker response systems*, *books*, the *overhead projector/Elmo*, *demonstration equipment*, or *miscellaneous objects*.

Table 20

Relative Frequency of Observed Teaching Practices- Harlow

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	1.00	Receive/memorize Information	1.00	Digital Tablet	0.89
Multimedia	0.89	Integrating Ideas	0.62	Pointers	0.45
Whole-class Discussion	0.62	Understanding Problem Solving	0.40	Computer and Slides	0.43
Worked Out Problems	0.55	Creating Ideas	0.04		
Comprehension Question	0.45				
Display Conceptual Questions	0.40				
Rhetorical Question	0.34				
Display Algorithmic Questions	0.30				
Online Techniques	0.13				
Illustration	0.09				
Desk Work	0.02				

Harlow's class took place virtually. Harlow shared her screen from her digital tablet. She started with blank slides that she wrote notes on during class while providing instruction. Harlow had her own camera on so students could see her while she was teaching. Students could turn their camera and microphones on, but most remained off throughout all three of the observations. Students used the chat feature to answer instructor posed questions and have class discussions.

Harlow started the class by creating casual conversation while giving students a few extra minutes to get logged in. She then moved on by displaying her course calendar and reminded students of upcoming assignment due dates and test dates. Harlow also reminded students of

available resources for help and encouraged her students to stay caught up on the homework and study frequently.

During her classes, Harlow used different colors to emphasize mathematical steps. She also used a digital pointer to indicate notes as she reiterated main ideas. Harlow asked the students conceptual, algorithmic, and comprehension questions throughout class. Students responded to Harlow's questions using the chat feature of the virtual platform. Harlow provided wait time for the students to process her questions and then respond. Additionally, she addressed any questions from the students that appeared in the chat box. Lastly, Harlow connected concepts to one another in her lecture and discussed common mistakes that the students should avoid on their homework.

Casey's Observation Summary

Casey's in-person class was observed three times. The total time spent observing Casey was 210 minutes. So, relative frequencies were calculated using 42 intervals of five minutes. The relative frequencies of behaviors on the TDOP that Casey exhibited during the observations are shown in Table 21. The codes on the TDOP that Casey did not manifest have been removed from the table.

The most frequent Teaching Method behavior that Casey performed was *lecture* (relative frequency 0.76). In addition to instruction, Casey created a lot of discussion between himself and the students, so *whole-class discussion* was the second most occurring teaching practice (relative frequency 0.69). During discussions Casey regularly asked the class *comprehension questions* (relative frequency 0.67). In the Cognitive Engagement category students were most frequently *receiving/memorizing information* (relative frequency 0.81). Students were also engaged in *understanding problem solving* during many of the intervals (relative frequency 0.76). The

Instructional Technology tool that Casey used most frequently was the *overhead projector/Elmo* (relative frequency 0.98). Casey combined using the projector with the classroom *blackboard/whiteboard* (relative frequency 0.69).

There were 10 behaviors from the TDOP that Casey did not exhibit. In the Teaching Methods category, Casey did not complete *demonstrations*, *case studies*, or *novel questions*. In the Cognitive Engagement category, Casey did not have the students *connect to the real world*. Lastly, in the Instructional Technology category, Casey did not utilize *posters*, *computer and slides*, *clicker response systems*, *demonstration equipment*, *miscellaneous objects*, or a *digital tablet*.

Table 21

Relative Frequency of Observed Teaching Practices- Casey

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	0.76	Receive/memorize Information	0.81	Overhead Projector/Elmo	0.98
Whole-Class Discussion	0.69	Understanding Problem Solving	0.76	Blackboard/ Whiteboard	0.69
Comprehension Question	0.67	Integrating Ideas	0.48	Book	0.17
Online Techniques	0.62	Creating Ideas	0.17	Pointers	0.12
Multimedia	0.60				
Worked Out Problems	0.60				
Display Algorithmic Questions	0.50				
Display Conceptual Questions	0.48				
Desk Work	0.26				
Small-group Work	0.12				
Rhetorical Question	0.10				
Illustration	0.02				

Casey's classes were held in person. However, Casey had pre-recorded his lectures, and students were expected to watch the lectures and take notes using Casey's note outlines prior to class. During class time, Casey summarized main points intermittently, but spent most of the class time giving students opportunities to explain their thinking on practice problems. Through this method Casey created whole-class discussions between the students and himself. Casey projected homework problems from the classroom computer; however, he worked all of the example problems on the whiteboard.

At the beginning of each class, Casey started by displaying the course website and making announcements. Announcements included assignment dates, quiz dates, and reminders of what lectures the students should complete before the next class. Next, Casey returned to the sections of material for that day's discussion. He asked students for any problems from the pre-class assigned problems that they wanted to discuss. Then Casey highlighted main concepts from the sections, asking the class both conceptual and comprehension type questions about the topic. After this review, Casey began working the student requested problems at the board. Casey took time to describe his thought process for getting from step to step and referenced formal definitions to explain why he chose to do a particular step. Additionally, Casey took time to pause and ask the class questions, which created student-centered discussions. Casey's process for going through problems created full class discussions where many of the students shared their ideas and participated. Casey also added additional problems to discuss with the class which highlighted common mistakes that students should avoid.

This portion of the class was paced by student discussion and took most of the class time. Nevertheless, in all three observations, Casey was able to work all the desired problems and answer all student questions. In the remaining class time, which varied in each observation, Casey provided students with post-class problems to work on at their desks. Casey encouraged students to ask questions as he walked around the room doing progress checks on lecture notes and pre-class problems. If a student had a question, he worked with them individually to answer their specific question. Although some students worked separately during this time, many grouped or paired together to work on the post-class problems.

Addison's Observation Summary

Addison's virtual classes were observed three times. The total time spent observing Addison was 225 minutes. So, relative frequencies were calculated based on 45 intervals of five minutes. The relative frequencies of behaviors from the TDOP that Addison demonstrated are shown in Table 22. Codes that were part of the TDOP that Addison did not manifest during observation have been removed from the table.

Addison's most frequent behavior in the Teaching Methods category was *lecture* (relative frequency 0.93). During direct instruction, Addison usually wrote down notes while speaking; thus, the relative frequency for *multimedia* was 0.91. Two other Teaching Methods behaviors with high occurrence were *working out problems* (relative frequency 0.89) and *whole-class discussion* (relative frequency 0.76). In the Cognitive Engagement category, Addison's students were most frequently *receiving/memorizing information* (relative frequency 0.93). Additionally, students were engaged in *understanding problem solving* for 73% of the coding intervals. In the Instructional Technology category, Addison utilized *computer and slides* most often (relative frequency 0.98). Moreover, he used his *digital tablet* (relative frequency 0.96) to actively write on the premade slides.

There were 10 behaviors from the TDOP that Addison did not exhibit. In the Teaching Methods category, Addison did not demonstrate *small-group work*, *case studies*, or *novel questions*. In the Cognitive Engagement category, Addison did not have students *create ideas*. Lastly, in the Instructional Technology category, Addison did not utilize *posters*, the *blackboard/whiteboard*, *clicker response systems*, *books*, the *overhead projector/Elmo*, or *miscellaneous objects*.

Table 22

Relative Frequency of Observed Teaching Practices- Addison

Teaching Methods	Relative Frequency	Cognitive Engagement	Relative Frequency	Instructional Technology	Relative Frequency
Lecture	0.93	Receive/memorize Information	0.93	Computer and Slides	0.98
Multimedia	0.91	Understanding Problem Solving	0.73	Digital Tablet	0.96
Worked Out Problems	0.89	Integrating Ideas	0.40	Demonstration Equipment	0.09
Whole-class Discussion	0.76	Connecting to the Real World	0.11	Pointers	0.02
Comprehension Question	0.62				
Display Algorithmic Questions	0.42				
Desk Work	0.40				
Display Conceptual Questions	0.29				
Rhetorical Question	0.18				
Illustration	0.07				
Online Techniques	0.07				
Demonstration	0.02				

Addison's class was held remotely using a virtual platform. Addison shared his computer screen with his students so they could see the premade slides of notes. These premade notes were posted on Addison's website along with premade student note outlines. Addison shared video of himself during the meetings. Students could turn on their video and microphone; however, most did not. Addison added material to the notes and wrote on them in real time using his digital tablet. He used colors to connect mathematical steps to instructions for completing problems.

Addison started each class with announcements about homework assignments and upcoming tests. Next, he started his instruction with main concepts. After a brief explanation of

the main concepts and definitions, Addison began working example problems with his students. Addison typically completed three examples for each concept. He followed a format where the first example was completed by Addison. In this first example he described his thought process for each step. The second problem was completed together as a whole-class, where Addison asked the students questions and prompted the class to guide him through the steps to complete the problem. Addison had students complete the third problem on their own. Since the class was remote, students worked individually on these problems. After providing students several minutes of work time on the problem, the class came back together to find the solution and discuss the problem. At this time, Addison asked students if they had any questions and answered any questions that he received in the virtual chat. Some students asked questions in the class chat while other students messaged Addison their questions privately. Addison's class structure followed that general process for the remaining time.

During that time, Addison also encouraged students to ask questions, to come to virtual office hours, and posed questions to help the students connect concepts. Addison reiterated definitions and wrote down "hints" while the students were working problems on their own. The hints helped the students move forward if they got stuck in their desk work. Occasionally, students asked for another example. If this was the case, Addison completed another problem before moving on to the next topic. Addison thanked students for their input and promoted student conversation.

Reflective Interviews

After completing all initial interviews and observations, the researcher summarized the initial data, then completed a reflective interview with each participant. The researcher started reflective interviews by discussing the participant's responses to the TBI. The researcher

confirmed that the summary of each question was accurate to the participant's thoughts. At this point, the participant was welcomed to add any additional thoughts or comments to their initial answer. The second part of the reflective interview was used as an opportunity for the researcher to clarify any questions from classroom observations or the participant's response on the TPI. In the third part of the reflective interview, the researcher asked every participant for feedback on the practices in the TPI that were infrequent for most of the participants. Lastly, each participant was asked about any practices that they would like to incorporate in their classes.

The following questions were asked at the end of each reflective interview:

1. Do you get feedback from students about their feelings about the exams or assignments?
2. Do you collaborate in creating department materials?
3. Do you discuss or share materials that you have made with colleagues?
4. Reading literature about teaching and course content was indicated as an infrequent teaching practice, what are your thoughts on literature about teaching?
5. Sitting in on a colleague's class to get or share ideas was indicated as an infrequent teaching practice, what are your thoughts about observing someone's class for ideas?
6. Is there anything that you would like to incorporate in your class that you haven't yet?
7. If so, what are the limitations preventing it?

The following paragraphs are a summary of each participant's responses in the reflective interview. The focus of the summary is the alignment between the Teaching Practices Inventory, the Teacher Beliefs Interview, and the classroom observations.

Finn's Reflective Interview

Finn's first addition in the reflective interview was about describing his role as a teacher. Finn added that it is important in his role to provide students with feedback on quizzes and tests.

This feedback included written comments on student work. He also explained that he uploads his exam and quiz keys to his course website. These keys show his written work step by step for each problem. His goal is that the students use the keys to compare to their own work and identify where they made mistakes.

Finn added that in choosing what to teach and what not to teach, when he is building his lesson notes, he tries to find examples that are similar to what students will see on the homework but aren't exactly the same. Finn explained that he wanted to complete midrange problems in terms of difficulty to complete with the students. If there is time to complete more than one example, Finn explained that he tries to find a more difficult example that has real world application in it or problems that have extra processes in them that the students might have to connect.

The researcher asked Finn to discuss the course projects he assigns it more depth. Finn clarified that the course projects are created for all the Fundamental College math classes at his college. Throughout the course, he assigns three major projects that are meant to be real world applications of the material. Students can work on the projects individually or in groups, but each student is required to submit their own essay style response for the project. Finn disclosed that he has mixed feelings about the projects. On one side, he can see the value for the students in tying the mathematical concepts to real world application. He added that if the students put in effort, it does help them make connections between concept, procedure, and application. However, many of the students put in minimal effort. This leads to the other side of Finn's opinion. He said that having the projects plus the mini-projects seems excessive. Furthermore, he would rather not assign group work. Finn explained that the mini-projects are take home quizzes that the students can work on in groups or individually; they can also see Finn in office hours or get help from a

tutor. The mini-projects consist of four to five procedural type problems and one to two conceptual questions.

In Finn's reply to student feedback, he explained that some of his assignments have open ended questions that require student feedback and opinion. He also explained that when students come to office hours, he takes the opportunity to discuss their thoughts on assignments, class structure, and anything that the students would like to share with him about the course.

Finn explained that he didn't really have any input on creating the department materials for the courses that he teaches. Nevertheless, Finn is willing to collaborate with colleagues and share the resources that he has created with other teachers. He added that he likes to see what other instructors are using for their lectures, and, if he likes it, he will incorporate it into his own.

When asked about reading current literature and research about teaching, Finn stated that he could see its potential and usefulness. However, since it is not a requirement of his job, he does not do it. He added that time constraints, especially with his other research duties, make the basics of teaching and grading a priority for that portion of his job. Furthermore, Finn stated that if research suggested that he radically change his teaching method, he would be worried about the time to accomplish such a change. He continued that if he made a large change in teaching method, and it did not work he worries about the effect that that change would have on the students in those classes. He does not want to risk students performing poorly in order to try new methods.

Finn commented that when he first started teaching, he discussed courses with colleagues frequently. Although it does happen less frequently now, Finn explained that if he does hear something that he likes from a colleague he will try to integrate those ideas into his classroom.

Finn added that over the last two years, the pandemic has made it more difficult to see colleagues and have discussions.

Finn explained that he has not thought about sitting in on a colleague's class due to time constraints. He added that he sees how observing could be beneficial. Finn claimed that he would be open to sitting in on someone's course, but scheduling, getting permission from a colleague, and time constraints with his other job expectations create difficulties.

Lastly, when asked if there was anything that he would like to incorporate in his courses that he has not yet, Finn responded that "nothing comes to mind." However, he said that he does think there are things that he could incorporate into his courses. Finn added that he only feels he is an average teacher, and he would like to improve. Yet, there are limitations to making changes because of time constraints both in and outside of the classroom. Finn also reiterated his previous fear about making changes that might have a negative impact on student learning. Finn commented, "I would feel terrible if I was not able to incorporate [the new method] correctly and if the students were to suffer because of that."

Alignment of Responses for Survey, Interviews, and Observations- Finn

Finn scored a 32 on the TPI. This score is approximately in the middle as scores can range from 0 to 69, meaning that the instructor implements some research-based teaching practices. From the TPI survey, Finn stated that 80% to 100% of class time was spent lecturing. Finn indicated that feedback was provided through graded homework assignments and exams. Moreover, Finn marked that he provided grading rubrics for projects and exam keys as other forms of feedback to the students. Finn indicated he used materials adapted and provided by colleagues, yet he did not indicate using departmental course materials for classes. Next, Finn indicated that students did have self-evaluation opportunities for their learning. Finn selected that

he occasionally discusses how to teach with other colleagues and rarely reads literature about teaching and learning.

In the first interview, Finn stated that opportunities for students to be self-reflective were included in his courses. He described that he tries to present multiple ways for understanding concepts. Finn explained that it is hard to know when students understand. This aligns with responses on the TPI indicating a large time spent on lecture and limited feedback provided to students. However, later in the interview, Finn did describe observing students solving problems and noting what questions they ask as indicators of learning. Students can ask questions at the start of any class, and Finn is willing to be flexible on the course pacing.

The classroom observations aligned with what Finn indicated on the TPI and in the interviews. Lecturing was observed in all coding segments which mostly involved working out problems. Comprehension questions were also used frequently. Students were mainly focused on receiving and memorizing information. Small group work was not observed in the classes, and this was not indicated on the TPI or in the interviews. Watching students solve problems was not seen in the observations, as was stated in the interview. Finn indicated that he taught in the traditional teacher-directed manner, and this aligned with what was seen in the classes.

In the reflective interview, Finn clarified details on assignments. First, Finn explained that on some assignments the students are allowed more than one attempt, but not all of the assignments. On the TPI, Finn had not indicated students could complete assignments again since they are not allowed to redo all assignments. Next, Finn described the course projects in the reflective interview as being designed by the department, which he did not initially indicate on the TPI. He also explained that most of the group work style assignments are due to department

requirements rather than his preference for them. This is consistent with Finn's teacher-centered responses to many of the TBI questions.

Blair's Reflective Interview

In her response to maximizing learning in her classroom, Blair added that during her live class meetings she really wants to provide students time to think and come to the solution on their own. She explained that in her videos she provides direct instruction for the students to gather information and to be introduced to concepts. This means that when the students meet with Blair live, they have seen the material and should be at a point of practicing skills. Therefore, Blair emphasized that it is integral for the students to have time to process the problems and to work on their own before she explains the solutions to the class.

Blair elaborated that in her role as an instructor she also sees herself as a mathematical resource for topics that extend beyond the course content. Blair described that as part of her unit on financial math, students are given a project about buying a home. Blair provides students with a scenario that they can use; however, many of the students choose to use their own life scenarios. Through this project Blair has helped her students extend math applications to their own lives and explained that some of her students have used this knowledge to actually pursue buying a home.

In her description of what to teach and what not to teach, Blair explained that her class occurred in two different formats: the pre-recorded lectures that are used to introduce content and the live class meetings that are used to review the lecture material and practice problems. Since the researcher only observed live classes, Blair was asked to describe a typical pre-recorded lecture. First, Blair explained that she provides visuals in the pre-recorded lectures. A pencil icon appears on her slides when the students should be taking notes, and a gear icon appears when the

students should be following along with an example. Next, Blair described that in the pre-recorded lectures her goal is to teach the concepts and course material. In the videos, she explains the concepts, definitions, and examples in a clear and concise way. Additionally, she does not address common mistakes or common questions in the videos; she addresses those during the live meetings. Blair elaborated that she adds personal elements to class meetings, whereas the pre-recorded lectures are direct content delivery and are somewhat flat.

In response to how students learn mathematics best, Blair added that she felt setting clear expectations were an integral part of learning. She described writing clear directions that were consistent. This included being consistent in directions between homework, quizzes, projects, study guides, and tests.

In response to knowing when learning is occurring in her class, Blair added that the written projects are another indicator of learning that she did not describe in the first interview. She explained that the written projects really give her an opportunity to see the students' understanding of the material through their application of the concepts in the real life scenarios. Blair further explained that she felt the projects better showed her how students are actually thinking because they have to write out their thoughts and communicate the math in words. Blair added that, "Since teaching remote I've gone with weighted rubric grading, and it has helped me a lot to decipher where exactly students are."

The researcher asked Blair about course topics covered in her syllabus. Blair confirmed that the list of topics was listed on her syllabus and that she simply missed indicating so on the TPI. She explained that the list of topics on the syllabus were more generalities of concepts and not a detailed list of exactly what would be taught in the course.

Next, the researcher asked Blair to discuss more about the projects she has added to her courses. Blair explained that she has modified the projects each semester that she uses them. In general, the projects are on applications of course content. Students are required to submit an essay style response, answering specific questions about their application of particular math concepts to a real-world scenario. Blair emphasized that the students have unlimited attempts on the project. She also added that she provides an example of a finished project that the student can reference. Blair reiterated that instructions and expectations for the project are provided as well as a list of learning outcomes that the project is intended to create. Blair stated that the projects can be completed individually or as a group. Additionally, the expectations for the project for group style work are explained separately from the expectations for individual style work. Blair described that at the beginning of the semester she polls the students about their preferences for working in a group versus working individually. Blair sends an email to all students who wish to work in groups via student emails then leaves it up to students to connect with one another. Blair stated, "I facilitate in letting the students know who wants to work together, but after that it is completely up to them."

Blair also described a typical in-class activity. As an example, she explained that she provided students with data from the local tourist authority for the past two years. Students were given instructions and a video example showing how to use Google Sheets. The students were then required to upload a screen shot of their completed Google Sheet, a bar graph or line chart of the data, and an explanation of their interpretation of the data and the visual. Blair stated that most of the mini-projects are meant to be applications of the concepts that the students can complete in a short amount of time. The mini-projects have open-ended solutions and are intended to have students explain their thinking.

In Blair's response to student feedback, she explained that she incorporated open-ended questions into her mini-project assignments to get feedback from her students. These feedback questions included asking students if they are comfortable navigating the course website platform, what course tools the students find most helpful, if they have feedback or recommendations for the instructional videos, and if the student would like to share anything with the instructor about their own progress. Blair stated that this type of student feedback is important to her because it is another way to get the students to talk with her. Additionally, Blair said it gives her a sense of what to use in her future classes, so she is constantly asking her students for their input.

In Blair's reply to collaboration in creating departmental material, she explained that the department has allowed her to create most of her own materials. Furthermore, these materials are available for other Fundamentals of College Math instructors to use if they wish. Blair also explained that in the College Algebra courses that she teaches, the department has made efforts to get instructor input in creating a departmentwide common final exam for the course. She stated that instructors are being surveyed and have an opportunity to discuss the concepts and questions that will be on the final each semester.

In Blair's reply to reading literature, she stated that she would like to read more literature about pedagogy. Blair said that reading literature is usually delayed because there are so many other responsibilities in teaching that come first. Although it takes her a while to get to it, Blair explained she does pay attention to information about pedagogy and workshops to improve teaching.

Blair explained that she frequently discusses teaching with her colleagues. Blair said that she has known some of her colleagues for a long time, so she is comfortable reaching out to ask

questions, get input on course topics, or compare grading. Blair commented that she usually talks to another colleague at least weekly.

When asked about observing a colleague's class, Blair stated that she would really like to sit in on other courses. She explained that she had asked a colleague to sit in on his class to get ideas before the pandemic, but she was not able to observe before the switch to remote learning occurred. Blair said that she has not observed classes in the past because she does not know the other instructors' comfort levels about her sitting in on their classes. Additionally, she said that she did not want to disrupt the flow of the class or have students behave differently because she was present in the class.

Blair stated that she would like to incorporate more student interaction and group work in her courses. She commented, "I wish that I could instill the benefits in that more, but they are doing fine without it." When asked about the limitations preventing more group work, Blair explained that it was primarily due to the current remote setting of her course. She said that if she was teaching in person, she would work much harder to create opportunities for student interaction. Blair added that in the current setting of remote learning group work might add unnecessary stress to her students, so she has not been assigning any required group work.

Alignment of Responses for Survey, Interviews, and Observations- Blair

Blair's score on the TPI was a 39. This score is slightly above the middle of TPI scores that range from 0 to 69; hence, Blair incorporates a fair amount of research-based teaching practices. Blair indicated on the TPI that she spends about 40%-60% of her class time lecturing. Additionally, Blair marked that she assigned projects and encouraged students to work collaboratively on their assignments. She provided students with feedback through their graded assignments, uploaded exam keys, and examples of projects along with the grading rubric for the

project. Blair also indicated that she explicitly encouraged her students to meet with her individually. Blair checked that she used or adapted materials made by colleagues but did not indicate that she used departmental materials. Blair recorded that students had opportunities for self-evaluation and opportunities to have some choice in their learning. She also indicated that she tries new teaching methods and materials. Lastly, Blair noted that she frequently discusses teaching with colleagues, but she infrequently reads literature relevant to the course she teaches.

In the first interview, Blair described supporting and guiding students through content and emphasizing creativity or multiple methods when solving problems. Blair explained that she assigns projects in her course. This aligns with her responses on the TPI, since projects create collaborative assignments while giving students opportunities for choice in their own learning. Furthermore, Blair emphasized guiding students through content in a way that targets conceptual knowledge over procedural memorization. This method corresponds to Blair's description that she only lectures 40%-60% of class time. Yet, Blair also discussed that a portion of class is focused on content delivery, so she expects more learning to occur outside of class.

In Blair's classroom observations, lecturing was observed for some portion of almost all of the intervals which is potentially a higher lecture percentage than Blair indicated on the TPI. However, Blair did not lecture the entirety of those intervals. Blair's students were given opportunities to work between lecture throughout the class. Moreover, several of the practice problems that Blair had the students try were application type problems. This aligned with Blair's described goals of emphasizing conceptual knowledge and making mathematics relevant.

During her reflective interview, Blair explained that giving students time to think and work on problems was an important aspect of class meetings. This aligned with what was seen during observations. Since Blair taught in a virtual setting, student activities were not observed

during the class meetings. Blair elaborated during her reflective interview that group work occurred during projects outside of the classroom, and students could choose whether they worked in a group or individually. Blair discussed that she would like to implement more student interactions and collaboration. This aligned with her earlier comments in the reflective interview. Blair emphasized the importance of students completing real world projects as a means of assessment in both the initial interview and the reflective interview.

Riley's Reflective Interview

In response to maximizing learning, Riley wanted to add that what she does in her classroom really depends on how many students are in the class that day. She described that the remote learning environment has been particularly difficult because some students log into class and do not actually participate which makes using breakout rooms and creating student interactions difficult. Another limiting factor, Riley explained, was creating student interaction with polling. This has been difficult because of the lack of mathematical symbols in typing. Next, Riley stated that she has been creating assignments that are not publisher based, so her remote students do not simply look up the work online. She described project style assignments such as creating art by graphing functions or application assignments for her trigonometry class that use non-standard numbers.

Riley added that her role as a teacher includes mentorship. She explained that students often ask advice about academics and careers. She described helping her students connect to the college and giving students a perspective from a professional capacity that is unique to teaching. Riley concluded that being a mentor to any of her students is an integral role of being a teacher. Next, Riley expressed that she felt that teaching is never static. She is always working to change and improve what she is doing in her classroom. Furthermore, she wants to reach as many

students as possible during her teaching: the high, middle, and low groups of students. She wants each of them to attain knowledge in her course.

Riley explained that she relies heavily on student responses to questions as an indicator of their understanding. She said that conversations in her classroom are important and that these conversations sometimes lead the class in an unexpected learning direction. Riley emphasized that now after two years of online learning it is really important to determine what the students know and to review the skills that they should have learned but are lacking.

In order to determine what to teach and what not to teach, Riley explained that she normally would work with other instructors. However, in the current post-pandemic setting, collaboration has been really difficult. In her specialized math courses, which are not taught frequently, Riley contacted other departments that teach follow up courses to her courses in order to discuss the math skills that students need to be successful in the follow up courses. Riley said that she intends for her math courses to be consistent with the expectations for the following courses that students will take. Next, Riley explained her desire to teach material that is relevant. Therefore, she uses problems that connect mathematics to other fields.

In her reply to how students learn mathematics best, Riley added that students communicating and working together outside of class is another important factor. In order to promote student interaction outside of class time, Riley created a second virtual room that the students can use to meet with one another at any time. Riley said that she is hopeful her students are using it to study for exams and to work together to build their knowledge.

Riley described seeing students' confidence levels change as another way that she knows learning is occurring in her classroom. She explained that as the semester has continued, conversations with students have evolved. These conversations contain greater depth of

knowledge indicated by better use of mathematical terms and the fact that the students appear excited to engage in them.

In reply to getting feedback from her students, Riley explained that she tries to have active conversations with her students. She stated that she has the students post formal discussions on the course website about how they are preparing for each exam. After exams, Riley depends on informal discussions with her students to determine what went well and what may need changed.

When asked about her thoughts on reading literature, Riley explained that she typically prefers taking courses and learning through those courses rather than reading research literature. She added that when she does read literature it is difficult to find articles relevant to what she is doing or teaching. Riley does skim articles sometimes but does not focus on reading literature frequently. Riley also commented that literature frequently describes a question and reveals an issue but does not seem to provide helpful solutions. So, with her time, she usually pursues learning through YouTube videos and online resources instead.

When asked about observing colleagues, Riley explained that she has recently been observing colleagues due to a job requirement. Riley commented that seeing what other instructors are doing is interesting and that it makes her curious about others. She also explained that it is difficult for the instructors not to do something slightly different when another instructor is there watching them, so one advantage of being observed virtually is that it is easier to forget that you are under observation. Riley discussed that although observing colleagues for her own growth could be beneficial, it is difficult to do under all of the time constraints of teaching.

In response to practices that Riley would like to incorporate in her classroom, she explained that she would really like better group work. Riley elaborated that she does have group

work in her classes, but when classes lack attendance, it is challenging to create meaningful student interaction. Moreover, she is always working to improve her group activities. Riley described that the group work she implements uses an active learning process where discussions and problems solving are leveraged to create student interaction rather than group work being merely group assignments that students must complete together for a grade. Riley explained that the largest limitations are making these activities happen in the remote learning environment, making sure all the students have access to the same technology, and making sure that when students are put into breakout rooms, they are actively participating with one another.

Alignment of Responses for Survey, Interviews, and Observations- Riley

Riley scored a 35 on the TPI. As this score is in the middle of scores that range from 0 to 69, Riley's score indicates that she uses a moderate amount of research-based teaching practices in her classroom. In the TPI survey, Riley indicated that she spent 60%-80% of her class time lecturing. Riley noted on the TPI that she encouraged students to work collaboratively on assignments and that there were assignments with explicit group work requirements. Riley selected that her students get feedback through graded assignments and exams as well as being provided with answer keys for assignments. She also indicated that she received feedback from her students regularly. Riley marked that she rarely discusses how to teach with colleagues and that she also rarely reads literature that is relevant to the course.

In the first interview, Riley emphasized student engagement through using learning interactives, polling, and breakout rooms. She stated that she wanted to foster student communication and engage the students to promote deeper connections to the material. This aligns with Riley's higher score in the In-Class Features and Activities section of the TPI. Riley also discussed that she listens to the feedback her students give her and will accommodate their

requests which aligns with her TPI responses. She stated that the students need to do math to learn it, which also aligns with her focus on student interaction and in class activities. However, as noted by her TPI responses, Riley still spends a large amount of class lecturing.

During her in-class observations, Riley lectured for some portion of all of the coding segments. This was a higher proportion of direct instruction than Riley had initially indicated on the TPI and in her first interview. Yet, Riley did have a high occurrence of whole-class discussions which aligned with her interview responses that student interaction was an important aspect of her classroom. Students were typically engaged in receiving information but were also engaged in problem solving for many of the coding intervals. Although some interactives were employed in the lecture slides, student polling and group work were not observed during the class meetings. Riley was observed making connections to the real world during her lessons through application problems and discussions of famous people in mathematical fields.

In the reflective interview, Riley explained some of the difficulties she had experienced throughout the semester in implementing group work in her classrooms. She explained that class attendance and technology with breakout rooms and polling have limited some of those types of interactions. She explained that in the current virtual setting she strives to create homework and projects that are relevant to the students' lives. Moreover, she relies heavily on student discussion and responses to questions to check for understanding which aligned with her actions during observations. Riley also explained that although she indicated on the TPI that she did not read literature, she is always working to make improvements as an instructor and frequently takes courses to learn about new teaching practices. Next, Riley also described that faculty interaction is limited, but she has reached out to other departments to get feedback for her courses. So, she does make efforts to communicate and collaborate with colleagues. Although

Riley initially indicated on the TPI that she had not sat in a colleagues' classes, she explained during her reflective interview that she has currently been observing other instructors as part of a mentorship role as part of her job requirements.

Taylor's Reflective Interview

In response to what to teach and what not to teach, Taylor added that a committee of instructors created the homework for the Precalculus I courses that she teaches. Taylor explained that her notes almost mirror the homework that the students are assigned. Taylor added a few extra problems to the notes and homework because she felt that they were important problems for the students to know. Taylor explained further that the committee started with the department chosen textbook for the courses, then went through each section determining the concepts that were important. The committee discussed any concepts that they did not feel were relevant and came to a consensus for including or excluding that material. Taylor also commented that she only teaches some topics if time allows.

Taylor added that although she primarily follows her schedule to determine when to move on to a new topic in her course, she also asked other instructors and referenced their pacing schedules. She explained that following the example of other instructors was really helpful in the beginning. Now, she still primarily uses her own teaching experience for determining when to move on to a new topic in her course.

In replying to how students learn mathematics best, Taylor added that she would really like to have students begin problems in her class. She described allowing students to have time to complete problems after seeing an example as something she would like to include in her future classes. This would allow students to try problems before completing their homework independently. Taylor explained that her goal in using this process in her future classes is to have

students test their skills and to build confidence while they are still in the classroom, especially so students can ask any questions that trying problems on their own might create.

In addition to her initial comments on how she knows when learning is occurring in her classroom, Taylor explained that prior to the pandemic she used to give test reviews and walk around the room to observe individual student work. She explained that this allowed her to discuss and to correct individual work with the students. Taylor said, "I can kind of gauge, and I can fix some of those mistakes before they take the actual test." She continued that it really made a difference for the students who take time and put effort into the review assignments. Furthermore, Taylor is hopeful to reintroduce this process in the upcoming semesters.

Taylor confirmed that she does provide her students with practice exams. She simply missed marking it on the TPI. She elaborated that she provides two practice versions for each test. She explains all of the problems for one of the practice versions during the class meeting prior to each exam.

Taylor clarified that she does get feedback from students in the course evaluations. Taylor also mentioned that she receives informal feedback from students who come to her office hours. She explained that many of her students appreciate all of the materials that she provides on her course website.

In reply to collaboration, Taylor answered that some of the courses in the department utilize communities of practice. Taylor described that these communities are for instructors who are teaching the same courses. The communities have scheduled meetings to discuss teaching the shared courses which provides instructors with an opportunity to discuss content or teaching practices with one another. Taylor also explained that her department has future goals to resume in-person meetings in which the instructors will have opportunities to conversate without a

formal meeting agenda. Lastly, Taylor explained that she has had a more difficult time collaborating and having casual discussions with colleagues, since many of them are still working remotely due to the pandemic. She is looking forward to having more people in the offices on a regular basis as more in-person courses restart on campus.

In reply to reading literature, Taylor explained that she occasionally reads literature. However, she prefers attending conferences to see research presentations instead. She stated that she gets to see many different methods at the various talks, so that is where she gets most of her knowledge about current teaching trends. Furthermore, Taylor has implemented some of the materials and techniques that she sees at conferences. She continued that conferences are her main source of professional development for teaching at the college level. Taylor added that another important aspect of the conferences is being able to collaborate and have discussions with other math instructors. Moreover, she reads conference proceedings for events that she was not able to attend. Lastly, Taylor commented that if she is preparing to present at a conference, she will read specific articles that relate to her presentation.

When asked about observing a colleague's class, Taylor explained that she has watched classes both to learn and also as a mentor. Taylor related some experiences of observing classes as part of evaluating others. Taylor also responded that she would like to observe other instructors in the upcoming semesters. She continued that she would like to see how instructors incorporate active learning in their classrooms. Taylor elaborated that she would really like to observe some of the newer techniques used in classrooms with an eventual goal of integrating those techniques into her own teaching.

When asked about any teaching practices that she would like to incorporate in her classroom, Taylor reiterated two things that she discussed previously in this interview. These

practices were giving students opportunities to work examples on their own during class time and incorporating more active learning techniques. She described that she felt it was important to walk around the room to see what students are doing. Next, she explained that she would also like to include more interactives in her lessons such as using Desmos. Taylor added, "It might make more sense to do something where you can manipulate and move things around." Taylor also stated that she wanted to work on asking students more efficient questions that create opportunities for student interaction rather than asking the class questions that have simple yes or no answers.

In response to limitations preventing these additions, Taylor described her reluctance to try new things. She admitted that sometimes she is afraid to try new things and that it is easy to become complacent in teaching. She added that making changes in teaching can be difficult, so it is easier to stick with what is comfortable. Taylor elaborated,

> I think it is important to have the attitude to want to change because, ultimately, we want to try to see what method is best for our students to use. And, I think if there's new tools that are out there, I think we need to be willing to try some new things… I think it is important as educators that we need to be open.

Furthermore, Taylor explained that she enjoys going to conferences so she can see new practices and new technology for teaching. Taylor stated that, in the future, she wants to challenge herself to teach in new ways. She added that her goal is to make small changes in the way she teaches to increase her comfort and to not become overwhelmed as she makes changes.

Alignment of Responses for Survey, Interviews, and Observations- Taylor

Taylor scored a 21 on the TPI. This score suggests that Taylor uses a low amount of research-based teaching practices in her classroom, since her score is in the lower third of

possible scores that range from 0 to 69. From the TPI survey, Taylor marked that she spent 80%-100% of class time lecturing. Next, Taylor stated that she developed her own course materials. On the TPI, Taylor did not indicate using any research-based practices in the Other category which includes new teaching methods, pre-post testing, or student surveys. She indicated that students had regular homework that contributed to their course grade and that students received feedback in the form of assignment keys and graded exams. Although not initially indicated on the TPI, Taylor did confirm during her reflective interview that she provides students with practice exams prior to the test date. Taylor selected that she regularly discusses how to teach courses with colleagues. However, she hardly ever reads literature that is relevant to the courses she teaches.

During the initial interview Taylor explained that her target is to deliver content to the students and to provide her students with as many resources as possible. This aligns with Taylor's responses on the TPI that suggested that she spends most of her class time providing direct instruction. Next, Taylor gauges understanding by using traditional methods of homework and exams. She also discussed student emails as a method of feedback. These practices align with Taylor's responses in the TPI which showed that her feedback from students is primarily aligned with traditional assessment methods with limited student communication. Taylor stated that students need to practice homework and do problems to learn which also aligns with her TPI responses and other interview responses that focus on providing students examples of homework problems. Taylor elaborated that although direct instruction is not promoted by research, she still feels that it is an effective teaching method when done well. Furthermore, she expressed that she receives positive feedback from her students and that her classes are always full, so she continues using her current teacher-centered practices.

Taylor's classroom observations were mostly consistent in what she had indicated on the TPI and what was discussed during the first interview. Taylor spent the majority of all coding segments providing direct instruction to her students. During this time she was at the board either describing concepts or working problems. This corresponded with her initial interview and TPI responses which stated that she focuses on content delivery and presenting students with precise step-by-step work for solving problems. Students were taking notes and receiving information while Taylor was lecturing. Taylor did indicate that she paused to ask questions during her classes on the TPI. However, Taylor did not pause instruction to ask for questions during any of the classroom observations.

During the reflective interview, Taylor discussed that although she does not read literature frequently, she does regularly attend conferences. Conferences are her preferred method for attaining new information. Despite attending conferences and seeing new teaching methods, Taylor communicated her discomfort in trying new things in her classroom. Taylor described several practices that she would like to implement in her classroom in the future. Although Taylor's teacher-centered practices are consistent with her responses in the initial interview and on the TPI, she articulated her ambitions to make changes to her classroom that would incorporate more research-based teaching practices during the reflective interview.

Harlow's Reflective Interview

In her response to how she knows when students understand, Harlow added that since she started requiring her students to attain a 75% or higher on one homework before they can move on to the next assignment, she has been getting more student questions via email. She explained that some of the students are sending lists of problems saying, "I don't know what to do." In response to these emails, Harlow asks the student to send their work, showing what they have

attempted on the problem so far. Harlow explained that it is important to see the student's work because it shows what the student is understanding and if they have attempted the problem. Harlow described in dismay that some of the students do not send their work for the problems, so it feels as if they just want her to do the problem for them. However, since Harlow described that it is essential that the students try the problems, she always requests photos of their work and will not provide solutions unless she can view the student's work. Harlow confirmed that her students have unlimited attempts on the homework problems, so, ideally, they should be able to work until they achieve a 100% on the assignment.

In response to student feedback, Harlow explained that she checks in with her students by asking informal questions. She said that she will ask students about their homework or email the student if she has not heard from them or has not seen them in class for an extended period of time. Lastly, she commented that she provides students with informal feedback as well as giving them reminders about certain assignments that are longer than normal.

Harlow confirmed that she does not have her students take a final exam. She requires that her students complete four exams throughout the semester to account for 60% of the student's grade instead. The rest of each student's grade is comprised of scores for homework, quizzes, and test practice problems. Harlow explained that she does not wish to create anxiety for her students by requiring a comprehensive final. Harlow explained that in the past she would let students take an optional final exam which would replace one of the first four exams. However, she quit the practice because she noticed that some students were skipping the exams on the chapters that were deemed more difficult and completing the comprehensive final instead, since they would not have to complete as many problems from those particular chapters.

In response to collaboration, Harlow explained that she does not mind showing colleagues her notes or showing them what she does for her courses. However, she is hesitant to provide someone with all of her material that she spent hours creating, because that person may not put any effort into the course and simply use what she created. Harlow described this scenario as proof of her concern, citing another instructor using one of her colleague's resources all semester without ever creating anything of their own. She said that it is extremely frustrating for the instructors who work hard to construct their own materials. So, Harlow is willing to show others her course material but usually does not provide it for them nor does she build material with colleagues.

Although Harlow rarely collaborates in building teaching materials, she did explain that she does have discussions with colleagues frequently. She commented that she has good discussions with other instructors during department meetings or at lunch with colleagues afterwards. Moreover, if she does have questions, she explained that she is comfortable emailing her colleagues and asking for their advice. Harlow described getting information from several instructors about their remote setup for teaching and now she teaches remotely using the method she liked best.

Harlow clarified that when she reads literature it is usually online material rather than research material from journals. Harlow said that she typically reads material once or twice a week, but the material is usually related to math history rather than teaching practices. She elaborated that incorporating math history into her lessons is one of her goals. She enjoys being able to describe background historical information to her students as she introduces topics.

In response to observing a colleague's class, Harlow explained that she has attended several instructors' classes but always from a position of evaluation. She stated that her

observations of other instructors and their methods mostly reaffirm that she prefers what she is already doing in her own classes. Harlow said that she can see value in some of the teaching practices she has observed, yet she still feels that her own practices are better for her own teaching style.

When asked if there was anything that she would like to incorporate into her classes, Harlow explained that she would really like to recreate better lecture videos. Harlow said that when she first made her recorded lecture videos, she was focused on them being perfect. However, she now feels that the videos are too impersonal and sterile. She would like to make new videos that feel more natural and mimic her virtual lectures that she has become more accustomed to while teaching remote courses.

Harlow responded that the limitations preventing changing her lecture videos are mostly her dislike of making the videos in general. She explained that she worries that she might leave information out. Furthermore, the process is lengthy. Since she has her current videos, she has delayed making the new videos.

Alignment of Responses for Survey, Interviews, and Observations- Harlow

Harlow scored a 24 on the TPI. This score is in the lower third of scores that range from 0 to 69 which illustrates that Harlow implements a modest amount of research-based teaching practices. In the TPI survey, Harlow indicated that she spent 80%-100% of her class time lecturing. Harlow marked on the TPI that feedback to students was provided through graded homework assignments and exams. Additionally, she stated that she does not have a final exam for her courses. Harlow noted on the TPI that she collected feedback from her students; she clarified during the reflective interview that this was through online class discussion boards and student emails. Harlow also indicated that she used very few in-class features and activities on

the TPI. Harlow marked that she regularly discusses how to teach courses with colleagues and regularly reads literature relevant to the courses that she teaches.

Harlow's responses in the first interview suggest that she is focused on content delivery. She described herself as a translator of the textbook, which aligns with her response on the TPI that she lectures most of her class time. Harlow emphasized homework completion as a method for checking student understanding. Moreover, Harlow stated that students should be asking her questions if they are having difficulties with the homework rather than merely copying an example. She also expressed concerns that she did not feel that group work was a productive use of class time. These responses are consistent with her TPI answers which suggest limited classroom activities and limited student interactions.

The classroom observations aligned with Harlow's responses in both the first interview and the TPI. Harlow lectured during all coding segments for most of each interval. Students were primarily engaged in receiving and memorizing information. Harlow did pose intermittent questions to her class during the observations that occasionally led to a brief class discussion, yet Harlow was the primary speaker in the discussion. This aligns with Harlow's low TPI section score for In-Class Activities and Features as well as her interview response that she did not like group work. Harlow's display of direct instruction further aligns with her interview and TPI responses where Harlow described curriculum coverage as a primary goal.

In her reflective interview, Harlow expressed that she prefers to "push concepts" rather than hands-on type activities where students "discover concepts." This sentiment aligns with Harlow's teacher-centered responses from the TPI and initial interview as well as her actions during her classroom observations. Harlow also explained that she prefers that students hold their questions until the end of the lesson or email her questions later which is consistent with her

previous comments and limited student interactions during the observed classes. Next, Harlow clarified that most of the literature she reads for her course is about math history, which she discusses during direct instruction, rather than literature about teaching practices. In the reflective interview, Harlow described that she does discuss her courses with her colleagues, and she has used their input in choosing teaching technology. However, she does not usually share her materials or collaborate to build materials with other instructors. Additionally, Harlow explained that when she has observed colleagues teaching, she usually favors her own methods over those that she has watched. All of these responses in the reflective interview are consistent with Harlow's teacher-centered style and low use of research-based teaching practices.

Casey's Reflective Interview

In response to his role as a teacher, Casey added that another part of his role is to create a welcoming learning environment. Casey explained that he wants to construct a classroom space where students feel comfortable asking questions and interacting with one another. So, part of his role is to build that environment. He described fostering this learning environment by being patient with student questions and reacting to their input in positive ways that encourage them to continue interacting in his classroom.

Although Casey relies on math department requirements in determining the mathematical concepts he teaches, he added that in determining what to focus on within each concept he relies heavily on student feedback from prior semesters. Casey described that through seeing student work over past semesters he has narrowed down common mistakes and discusses specific processes with students to help them avoid those pitfalls. Next, Casey explained that in choosing homework problems he tries to focus on the core content for each section of the textbook.

Additionally, he chooses examples that connect concepts or reinforce other math skills while practicing the new math concept.

In reply to student feedback, Casey explained that he usually gets informal feedback from his students almost every class. He described starting the class by asking students how they feel about the topics, how they feel about the difficulty of the material, and their opinions about the testing format especially because of changes in learning due to the pandemic. Casey also stated that he is constantly looking for student input during class discussions and with individual students when he provides work time in class. Casey commented that he really wants to know what his students are struggling with and what they have questions about.

Casey answered that he has recently been collaborating in making department materials. He explained that his math department has asked for instructor input in constructing the common department final. So, everyone teaching the course is collaborating to create common materials. Most of this collaboration has been completed online through email and shared Google Sheets.

Next, Casey explained that he frequently has discussions with his colleagues about their teaching practices or about sharing ideas and material. Additionally, Casey said that during course meetings instructors are encouraged to share their teaching techniques with one another, especially if a new technique is yielding positive results. Casey also described discussing grading or student interactions with his colleagues. He said that having his colleagues to converse with was an important resource.

When asked about reading literature, Casey answered that while he was working on his graduate degree, he did read literature about teaching practices and presenting material. However, since he has not been enrolled in classes in some time, he does not read literature very

frequently. Casey explained that the biggest reason he does not read literature is due to time constraints and other teaching responsibilities that have higher priority.

In response to observing a colleague's class, Casey commented that he thought everyone should sit in on another instructor's course at least once a semester. He explained that getting ideas from observing others would be helpful and that he is always curious what other instructors are incorporating in their classes. Despite Casey's willingness to observe other instructors, he has not observed colleagues often because it is outside of his job requirements.

Casey explained that he would like to incorporate more student interactions in his classes. He would like for students to collaborate with one another where they discuss problems and work together. The biggest limitation for Casey in creating more collaboration between his students is his fear that instead of students working together, students will be more motivated to copy a peer's work. He explained further that when he provides work time in class, that work time is for assignments that he does not grade because he hopes this will encourage the students to collaborate in learning versus cheating to get points on an assignment.

Alignment of Responses for Survey, Interviews, and Observations- Casey

Casey scored a 36 on the TPI. Since this score is slightly above the middle score in the range of 0 to 69, it suggests that Casey implements a medium amount of research-based practices in his classroom. On the TPI survey, Casey stated that he spends 40% to 60% of his class time lecturing. Casey indicated that he provides lecture videos and follow-along notes that students are asked to view and complete before class. Casey also marked that some student assignments are graded, and some are not. He indicated that his students were also encouraged to work collaboratively on these assignments. Casey noted that he provides feedback to students through graded assignments and exams and also feedback during class work time when he walks around

the room viewing student work. Additionally, Casey encourages students to meet individually to discuss their work, and students have opportunities to redo work to improve their grade. Casey indicated that students have opportunities for self-evaluation of learning. He also noted that he tries new teaching methods regularly. However, Casey marked that he rarely discusses teaching with colleagues and that he rarely reads literature that is relevant to his course.

In the initial interview, Casey explained that a large portion of his class time is spent having whole-class discussions and answering student questions. He elaborated that his goal is to prompt student thinking about why concepts work and to correct any mistakes they might be making during conversations in class. Furthermore, Casey discussed viewing student work and seeing improvements between students' work on pre-class problems and post-class problems. These responses align with Casey's TPI answers which indicate that students have opportunities for self-evaluation, students have time to correct mistakes in their own work, and that students have periods to collaborate with one another or have individual discussions with Casey. Additionally, Casey stated that his pre-made materials that students work through before class are based on department curriculum requirements. This aligns with Casey's TPI response that he uses departmental course materials.

Casey's classroom observations aligned with his interview and survey responses. Lecture was observed for small portions in three-quarters of the coding intervals, and whole-class discussion was observed during almost as many of the intervals. Students were engaged in both receiving information and problem solving during most of the coding segments. Furthermore, Casey was seen monitoring student work and having individual conversations with students about problem solving while students were observed working in small groups or pairs.

In the reflective interview, Casey described additional methods that he applies to create a more student-centered learning environment. These comments were consistent with his actions during observations and his responses on the TPI and initial interview. Casey elaborated that although he follows departmental materials as indicated on the TPI, he uses his experience and student feedback to enhance the content he teaches. Next, Casey explained that he gets feedback from students in their work, as described on the TPI, but also relies on informal feedback from students through conversations. Casey also discussed that he would like to observe other instructors to see what they incorporate in their courses which aligns with Casey's interest in trying new teaching methods. Lastly, Casey discussed his desire to create more student interactions in his classroom. This is consistent with Casey's student-centered like responses to many of the TBI questions.

Addison's Reflective Interview

In his reply to knowing when students understand, Addison added that he relies on students' responses to posed questions. He said that listening to students' explanations of their work has been especially important in the remote learning environment. Typically, Addison would have walked around the room and viewed student work to check for understanding. Since he cannot view student work in the virtual classroom, he asks students to explain their process for completing the examples that they work on their own. Next, Addison explained that he encourages students to respond to his questions verbally, using the class chat, or using private messages. He wants the students to communicate with him in whatever way they are most comfortable. Moreover, Addison tries to encourage students when they answer aloud so they will be more willing to participate again in the future. He said that he has noticed more participation and engagement in his classes later in the semester which he attributes to his encouraging

responses in the beginning of the semester. Students are also welcomed to ask questions through private messages to the instructor. Addison stated that he repeats privately asked questions aloud back to the class, so he can respond to the entire class. He feels that these student questions provide a strong learning opportunity for everyone.

Addison explained in more depth how he chooses what to teach and what not to teach. Since the math department requires that certain topics are taught, Addison elaborated that he compares the required material to the math department exams. After comparison, he focuses on all the material the students must know for these exams and cuts other sections so he can maximize his time on the material that the students are tested on. Then, at the end of the semester, he spends any extra class time going through sections of material that are pre-requisite for other math courses but not essential for the students to know in his math course.

Addison explained that in choosing his examples to do with the class, he typically picks the more difficult exercises from the book that are similar to the students' homework. Lastly, Addison said that if the textbook is confusing, he will rewrite sections in his own way and teach the concepts in the most straightforward way possible. In these cases, he pulls extra resources together and assigns homework from resources other than the class textbook.

In response to how students learn mathematics best, Addison added that some of his students have been reading the material before class which has improved their class participation. Next, he discussed that in the virtual environment his students are becoming more comfortable having discussions and answering one another's questions in the chat, sometimes before he can respond. Addison explained that he is glad that discussions are taking place again because student interaction has been difficult to replicate in the remote environment. Furthermore, he

believes that not having discussions as the students would in regular classrooms has perhaps hindered the learning process.

Addison stated that student emails are another way that he knows learning is occurring in his class. He described students emailing questions about homework where they send their correct work, but the homework program marked them wrong due to formatting. Addison explained that he sees learning is occurring through viewing the students' work when they request his explanation of homework problems. He commented that students are doing the work correctly for the most part. He usually only has to explain how to enter the solution into the program. For example, reminding the students to enter "t" as their variable, because it is the variable in the problem when they entered "x" out of habit instead.

Addison clarified that he does not have projects for his College Algebra courses, but he does have projects for other courses that he teaches. He explained further that the reason he has the projects in other courses is due to the department requirements for those courses. Addison stated that he dislikes the projects, mostly because of how difficult the projects are to grade. After the first semester of assigning projects, he started providing examples of an "A" project and an "A" presentation. Addison said that after his improvements he does not mind the projects as much, but he still gets negative feedback from students. Most of their negative feedback is in regard to working with their peers and trying to communicate with one another outside of class time. In order to mitigate this problem he has given students a choice in working as a team or working individually. Addison commented that he can see the benefit for students who actually communicate with their peers or who work individually. He said that students who work individually seem to understand more. Yet, he has not made the projects completely individual

because he does think that the projects are better as group assignments when the courses are in person.

In response to student feedback, Addison answered that toward the end of the semester he has a class discussion with his students about their thoughts and feedback for the course. He asks the students what was helpful in the course, if they have ideas for improvement, and other questions about their opinions of the course. Additionally, he does have one-on-one conversations with students about their feelings for the course. Addison summarized, "I do try to get feedback from them, because I would like to make the class a better class. And not just about testing. I would like [the class] to be better for each student individually." Furthermore, Addison does implement changes based on student feedback. He described an example with one of his courses in which he rewrote a chapter of notes and changed it drastically from the book because of student feedback. Addison said that the following semester his students performed much better on that chapter.

In regard to departmental collaboration, Addison answered that efforts are being made to get input from instructors for the courses that have a common final. There have also been recent efforts to improve the course based on instructor feedback. Addison stated that he was excited to participate in the committee to improve the course.

Next, Addison explained that he is happy to share his material with other instructors. He stated that sharing materials is part of teaching and that he has also received material from other instructors when he has needed help with a course. Addison described trading materials and ideas for the courses he teaches. Moreover, if he tries something new that yields positive results, he passes it on to his colleagues.

Addison stated that he is currently reading literature because of the courses that he is taking presently as a student himself. He said that reading literature more frequently is a change that occurred during the semester of this study. Based on his readings, there are teaching practices that he would like to promote in his own teaching.

In reply to discussing the courses he teaches with colleagues, Addison responded that he regularly talks to his colleagues about teaching. However, he explained that the conversations are normally casual conversations about how classes are performing. He rarely has conversations with his colleagues about teaching practices or methods. He added that when he has a question about teaching methods, he does not usually seek advice from his colleagues.

When asked about observing a colleague's class, Addison explained that he has never had the opportunity or desire to attend someone else's course. He said that it is all based on time constraints. Many of the colleagues he would be interested in watching and those with whom he is comfortable asking to observe teach during the same time as him or teach classes that conflict with his schedule in the afternoon or evenings.

Addison explained that he would like to incorporate ideas from recent readings into his future classes. He stated that one article he read discussed encouraging students to engage in their college community because it showed positive results for their academic performance. So, in his classes next semester he plans to promote student involvement in the campus community. He has not done so yet, because he only recently read about the benefits it had for college students in the research article.

Next, Addison would also like to have future students create a workbook or notebook that he checks periodically. The purpose of the graded workbook would be to promote better notetaking and completion of extra practice problems. Addison explained that the main

limitation in requiring student notebooks is his concern that it would add to his workload and add to the students' workloads without benefiting student performance. He said that he would like to find research that substantiates that teacher required workbooks are beneficial to students before he requires them in his classroom.

Alignment of Responses for Survey, Interviews, and Observations- Addison

Addison scored a 29 on the TPI. Since this score is slightly below the middle of scores that range from 0 to 69, it suggests that Addison implements some research-based teaching practices. Addison clarified during the reflective interview that he spends 80% to 100% of class time lecturing, because he accidentally skipped the question on the TPI. Addison indicated that students are asked to read before class. Addison also marked that students had regular homework assignments that contributed to course grades and project assignments. Furthermore, he indicated that he encourages students to work collaboratively on assignments; some of those assignments are explicitly group assignments. On the TPI, Addison noted that feedback to students included assignments that could be redone after evaluation, graded assignments and exams, and that he specifically encourages students to meet with him. Next, Addison indicated that he occasionally discusses how to teach courses with colleagues, and he never reads literature relevant to his course.

In the initial interview, Addison discussed working through examples and asking students questions to create engagement during instruction. He described checking for understanding using assignments and assessments. These responses align with Addison's higher score for the Assignment section and the Feedback and Testing section of the TPI. He explained that he moves forward when he has covered the necessary content; however, he does get student feedback and will complete extra examples at his students' requests. Addison described creating

student interactions during class by promoting student work time and collaboration. This aligns with his TPI answers that indicate students have opportunities to redo work after receiving feedback and are encouraged to work collaboratively.

During Addison's observations, lecture was observed for almost all of the intervals. He also spent a majority of the coding segments working out problems. Additionally, whole-class discussions occurred during many of the coding intervals. This aligns with Addison's responses in the initial interview that he lectures frequently and uses posed questions as a technique to promote student engagement and communication. Students were primarily engaged in receiving and memorizing information or in problem solving. Although Addison was not able to view student work because of the remote environment, he did provide students with work time after which he would have students explain how they completed the problem. These observations were consistent with Addison's interview discussion describing how he knows when students understand.

In the reflective interview, Addison reiterated how important student responses are for checking understanding in his current classroom setting. Addison discussed this process in the initial interview, and it was viewed during classroom observations. Addison indicated on the TPI that he used adapted materials from colleagues. However, in the initial interview he discussed departmental requirements, and in the reflective interview he clarified that his goal is to meet the department's requirements while reducing the material to key topics that are in the common final. Next, Addison explained that only some of his students read materials before class, but he does not require it for his College Algebra course. Furthermore, student group projects are required for other courses that he teaches, but he does not assign those projects for his College Algebra course. His indication of group projects on the TPI was in reference to his other course.

Moreover, Addison shared his frustrations in requiring group projects. These vexations included difficulty in grading group projects and that students struggle to work together in the virtual environment. This explanation of Addison's view on group projects is consistent with Addison's teacher-centered responses in the initial interview. Addison also elaborated that although he initially marked that he never read literature on the TPI, he has been reading literature recently. Additionally, he explained that because of this literature he would like to implement changes in his future classes.

Chapter 5

Discussion and Implications

In efforts to improve student success rates in college level math courses, researchers have identified several problems. First, there is limited training in pedagogy and learning theories for collegiate STEM faculty (Brown et al., 2006; Gandhi-Lee et al., 2015; Speer & Hald, 2008). Second, the extent to which faculty are using research-based teaching practices requires further research (Hora, 2016). Third, the reasons faculty employ the teaching methods they do must be better understood (Hora & Anderson, 2012; Oleson & Hora, 2013). Research suggests that in order to understand teaching practices enacted by faculty, it is important to understand the teaching beliefs said faculty hold (Ernest, 1994; Hora & Ferrare, 2013; Kane et al., 2002; Luft & Roehrig, 2007). This research study had two main goals with the purpose of investigating ideas connected to the research areas described above. First, to determine common teaching practices of post-secondary mathematics instructors which is meant to add to the research knowledge about post-secondary mathematics instructors and their perceptions of teaching practices. Second, to explore relationships between reported teaching practices, faculty teaching beliefs, and actual teaching practices to gain a better understanding for the reasons faculty implement their chosen teaching methods.

This study was conducted at two large public colleges in the Southwestern United States. The researcher utilized an explanatory sequential mixed methods design with a case selection and case study variant (quant → QUAL [Case Study]). To achieve this, quantitative data was collected using the Teaching Practices Inventory (TPI; Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014). Next, the researcher purposively sampled specific survey respondents to participate in qualitative data collection. Each of the seven qualitative

participants completed an initial interview following the Teacher Beliefs Interview (TBI; Luft & Roehrig, 2007), then three classroom observations that were coded using the Teaching Dimensions Observation Protocol (TDOP; Hora & Ferrare, 2013), and, lastly, an exit interview following reflective practices (Li, 2013; Speer, 2005).

Through the use of several types of data collection in a case study setting, this research study attempted to identify deep connections between teaching beliefs and teaching practices. The study leveraged several types of data to avoid limitations of solely self-reported data (Kane et al. 2002; Speer 2005) and applied reflective interview practices (Li, 2013; Speer, 2005) to promote shared understanding and to provide time to discuss discrepancies. Furthermore, the research aimed to present a comprehensive view of each participant's teaching beliefs and teaching practices in order to answer the research question.

This chapter is organized into seven main sections. The first section summarizes results for the TPI survey for the entire sample of 21 participants. The second section summarizes results for each of the seven qualitative participants as individual case studies. These findings are briefly summarized in Table 23 at the end of the second section. The third section describes comparisons of alignment between the seven case study participants. The fourth section is a brief discussion of results. The fifth section describes implications of this research. The sixth section describes limitations of the study. Lastly, the seventh section discusses recommendations for future research.

Research Question

What is the relationship between reported teaching practices, teaching beliefs, and actual teaching practices for collegiate math instructors?

TPI Results for Entire Sample

Mathematics instructors from two colleges were invited to participate in the initial Teaching Practices Inventory survey. There were 21 complete survey responses. The average score for the TPI was 35.14 out of 69. This indicates that on average each of the survey instructors are employing about half of the research-based practices listed on the TPI. Since there are 53 research-based items on the TPI, results suggest that each instructor is typically implementing 26 to 27 of these research-based teaching practices.

The highest section average was in the Feedback and Testing section of the TPI. This suggests that the instructors in the sample implemented the most research-based practices for Feedback and Testing. These teaching practices included providing students with graded assignments and exams, providing students with answer keys for exams and projects, providing students with opportunities to redo work to improve their grade, encouraging students to meet with the instructor individually, receiving feedback about the course from the students, and receiving midterm course evaluations from the students. This is different from prior research that found 78 undergraduate mathematics instructors from Saudi Arabia had low scores in the Feedback and Testing section of the TPI (Alsharif & Alamri, 2019).

The second highest average score was in the Assignments section of the TPI, suggesting many of the instructors applied research-based practices from this section. The research-based practices in this section included assigning homework in short intervals of two weeks or less that contributed to the student's course grade, assigning projects, encouraging students to collaborate on their assignments, and requiring explicit group assignments.

The lowest section average was in the Other category of the TPI. This indicates infrequent use of these research-based practices by the instructors in the sample. The research-

based practices in this section included diagnostic measurements such as utilizing pre and post testing, assessment of skills at the beginning of the course, and comparisons of the same assessments over different course sections. This section also contained methods for supporting students. These practices included assignments in which students have individual choice (i.e. project variations), opportunities for students to self-evaluate, and attempting new teaching methods. Research by Alsharif and Alamri (2019) demonstrated similar results. They reported that their sample of 78 instructors also had the lowest scores in this category (Alsharif & Alamri, 2019).

The next lowest average score was in the Course Information section of the TPI which suggests that the instructors in the sample are not implementing very many of these research-based practices. The teaching practices in this section included providing students with a list of topics to be covered, providing students with a topics list that discusses specific competencies for the course, providing students with a list of skills that they will gain which are not topic specific, and providing students with a list of goals for the course. Results from the TPI illustrated that many of the instructors only provide a basic list of topics on their syllabus. However, more in-depth information described in the practices has been shown to be beneficial for students (Wieman & Gilbert, 2014).

Alsharif and Alamri (2019) found that their sample of instructors earned the highest scores in the Collaboration section of the TPI. However, the instructors in my sample scored relatively low in this category. The Collaboration section included the following research-based practices: discussing how to teach with a colleague, reading literature relevant to the course, and observing another instructor's course to gain knowledge of other teaching practices. Qualitative participants were specifically asked about these three practices during the reflective interviews.

Many of the qualitative participants explained that they do have discussions with colleagues. However, many of these conversations are not specifically about how to teach. Several of the qualitative participants also described the remote work environment as a limiting factor because of an inability to physically see their colleagues. Most of the qualitative participants identified similar reasons as to why they do not read literature relevant to teaching and why they do not observe colleagues to gain ideas for teaching. The first reason was due to time constraints. Several qualitative participants explained that other teaching responsibilities were prioritized over reading literature or observing others. The second commonly discussed reason was that both reading literature and observations were not part of their job requirements. These responses suggest that these practices are unlikely to be implemented without an external motivator or a change in perspective to view these practices as beneficial. These factors align with prior research in non-STEM fields, that indicated time shortages and teaching workloads negatively impacted the adoption of some teaching practices (Nghia, 2017).

Summary of each Participant

Finn

Finn taught Fundamentals of College Math courses for the semester of this study. His courses were held in person. Finn's score on the TPI was 32 out of 69 which was in the middle range of scores among the qualitative participants. In Finn's responses to the TBI interview questions, two responses were coded as *Traditional*, three responses were coded as *Instructional*, and two responses were coded as *Emerging Constructivist*. During observations, Finn's most frequent teaching practices, occurring in over 80% of the coding intervals were *lecture*, using *multimedia*, asking *comprehension questions*, and *working out problems*.

Finn's initial interview responses were mainly teacher-centered. Five of Finn's responses were coded on the teacher-centered side of the teacher-centered to student-centered beliefs continuum. The other two responses were coded on the student-centered side of the spectrum. Additionally, Finn describes himself as having a "traditional" teaching style. This self-described "traditional" style was also observed in his classroom and supported by his high frequency of *lecture*. This was also consistent with Finn's low score in the In-Class Features and Activities section of the TPI. Yet, two of Finn's responses were on the student-centered side of the beliefs continuum; these responses suggest that Finn does attempt to adjust his teaching relative to student input. His actions to obtain student input were evidenced by posing questions. Finn asked at least one of each type of the coded questions (*comprehension questions*, *display conceptual questions*, and *display algorithmic questions*) in over 50% of the coding intervals. In both the case of Finn's style of direct instruction and Finn's use of posed questions to obtain student input while checking for understanding, Finn's espoused theories (self-reported information and interview responses) were consistent with his theories-in-use (observed teaching practices).

Finn earned high scores in both the Assignments section and the Feedback and Testing section of the TPI. Half of the points he earned on the TPI were in these two categories alone. The practices that Finn reported in these categories were assigning projects, encouragement for students to work collaboratively, explicit group assignments, providing students with rubrics for projects, and obtaining feedback from students. Since these practices are somewhat inconsistent with teacher-centered beliefs and student collaboration was not observed during class time, Finn was asked to discuss these practices during the reflective interview. This provided Finn with an opportunity to connect his beliefs and practices (Speer, 2008). In the reflective interview, Finn

described that providing students with feedback on quizzes and testing was important in his role as a teacher which added alignment between his beliefs and self-reported practices.

Finn's espoused theories and theories-in-use were inconsistent in his teaching practice of requiring group projects. During his description of his group assignments, Finn elaborated that he assigns them because of departmental requirements. He explained that he would rather not assign group work, because he felt that the students put minimal effort into the group projects and do not gain the intended conceptual knowledge from the projects. This exemplifies Norton and colleagues (2005) conclusion that instructors make compromises between their teaching beliefs and their teaching practices based on influences such as academic setting. In this case, Finn's teaching practices were altered by external expectations of the department. This also supports Hora and Anderson's (2012) findings describing that faculty teaching practices are impacted by the subject discipline and department in which they teach. Furthermore, this may indicate that without an external expectation from the department Finn would be more consistent in his beliefs (espoused theories) and his teaching practices (theories-in-use). Finn's assignments reflect the department requirements, but his classroom teaching practices maintain consistency with his own preference for direct instruction. This substantiates the possibility that some of Finn's teaching practices that are more student-centered are only implemented to a minimal degree because they are required as opposed to being consistent with his own teaching beliefs.

Blair

Blair taught Fundamentals of College Math-Corequisite courses for the semester of this study. Her courses were held remotely using a virtual platform. Blair's score on the TPI was 39 out of 69 which was the highest score of the qualitative participants. In Blair's responses to the TBI interview questions, one response was coded as *Traditional*, four responses were coded as

Transitional, and two responses were coded as *Emerging Constructivist*. Blair's only teaching practice during observations that occurred in over 80% of the coding intervals was *lecture*.

Blair's responses in the TBI interview were mostly in the center of the student-centered to teacher-centered beliefs continuum. Even so, two of the three of the responses that were not in the center of the spectrum were coded on the student-centered side of the continuum. This suggests that Blair's teaching beliefs tend to be more student-centered. Many of Blair's responses in the initial interview emphasized her focus on creating student understanding of mathematics that is conceptual rather than procedural. Her tendency toward student-centered beliefs is consistent with her higher score on the TPI that suggests she uses a fair amount of research-based teaching practices. Blair scored almost half or more of the respective points in each one of the TPI sections. Her two highest section scores on the TPI were in the Assignment section and the Feedback and Testing section. These sections included research-based practices such as assigning projects, encouragement for students to work collaboratively, providing students with grading rubrics, and encouragement for students to meet individually with the instructor.

Despite Blair's responses tending toward student-centered beliefs and her TPI score being high among the qualitative participants, some of her espoused theories were inconsistent with her theories-in-use that were viewed during classroom observations. Blair exhibited more direct instruction during observations than she had self-reported in the TPI. Furthermore, Blair only asked *comprehension questions* in 33% of the coding intervals. She did not ask any *display algorithmic questions* or *display conceptual questions* throughout the observations. As a result, most of the *whole-class discussions* that occurred in 49% of the coding intervals were led by Blair with students responding in simple yes and no answers.

Although a discrepancy exists, there is some consistency between Blair's self-reported practice and classroom practice. One indication of consistency is that Blair only scored 7 out of 15 on the In-Class Features and Activities section of the TPI. Her lower score in this section suggests that she may utilize more teacher-centered practices during class. Recalling Blair's high scores in the Assignments section and in the Feedback and Testing section of the TPI provides further evidence that more of Blair's student-centered teaching practices occur outside of the classroom. For example, Blair discussed the importance of the projects and mini-projects that she assigns to her students. She described several reasons that the projects were a significant part of her teaching repertoire in the TBI interview, and she reiterated this perspective in the reflective interview.

Gandhi-Lee and colleagues (2015) described teaching practices applied in the classroom are the result of compromises between instructors' idealized beliefs about teaching and the instructors' perception of students' capabilities and context-based factors. In her initial interview, Blair described "meeting the students where they are at in their knowledge," as well as other similar comments that referenced matching students' abilities. First, this suggests that Blair is making a compromise where she yields in her ideal teaching beliefs (espoused theories) in order to implement teaching practices (theories-in-use) that match her students' abilities. Yet, it reaffirms Blair's student-centered beliefs that indicate she prioritizes student understanding over content delivery. Furthermore, Blair explained that she desires more collaboration and student interaction in her classroom. She also described that while she would like to incorporate more group interactions, she feels possibilities are limited as long as she is teaching in a virtual classroom setting.

Riley

Riley taught Precalculus II courses for the semester of this study. Her courses were held remotely using a virtual platform. Riley's TPI score was 35 out of 69 which was in the range of high scores for the qualitative participants. In Riley's responses to the TBI interview questions, two responses were coded as *Traditional*, one response was coded as *Instructional*, one response was coded as *Transitional*, two responses were coded as *Emerging Constructivist*, and one response was coded as *Experienced Constructivist*. Riley's most frequent teaching practices exhibited during observations in more than 80% of the coding intervals were *lecture* and using *multimedia*.

Riley's responses were coded into each of the five categories on the teacher-centered to student-centered beliefs continuum. One of Riley's responses was in the center of the spectrum, three were on the teacher-centered side of the spectrum, and three were on the student-centered side of the spectrum. This suggests that Riley's beliefs do not tend toward either end of the spectrum but, instead, depend on the context. During the initial interview, many of Riley's responses emphasized students being active in their learning through discourse and participation. This aligns with Riley's relatively high TPI score that indicates she uses a moderate amount of research-based teaching practices. Additionally, amongst the qualitative participants Riley scored the highest in the In-Class Features and Activities section of the TPI. These TPI scores and interview responses align with student-centered beliefs.

Nonetheless, some of Riley's responses on the TBI were teacher-centered. Her teacher-centered responses focused on content-delivery in the following situations: determining when to move on in her course, deciding what to teach, and knowing when learning is occurring. In both the case of determining when to move on and deciding what to teach, Riley defaulted to content

standards determined by the department. This suggests that Riley follows more teacher-centered beliefs when external factors have greater impact. This aligns with other research findings which expressed that faculty merge teaching beliefs and external expectations (Hora & Anderson, 2012; Norton et al., 2005).

Classroom observations exhibited a mixture of teaching practices that were in alignment with Riley's espoused theories while some practices were inconsistent with Riley's espoused theories. Evidence of alignment with Riley's teaching beliefs (espoused theories) about student communication and participation were manifested in Riley's implementation of *whole-class discussion*, *working out problems*, *comprehension questions*, *display algorithmic questions*, *rhetorical questions*, and *display conceptual questions*. All of which occurred in at least 29% of the coding intervals. Of those teaching practices, w*hole-class discussion* occurred most frequently, which was in 77% of the coding intervals. However, Riley's espoused teaching beliefs that focus on collaborative activities were not seen during classroom observations. Instead, Riley displayed more direct instruction, which is a teacher-centered practice. She *lectured* for some portion of 100% of the coding intervals. This was a large discrepancy between Riley's espoused theory (teaching belief) and theory-in-use (teaching practice). According to Argyris (1995) fundamental mismatches between espoused theories and theories-in-use can occur.

Li (2013) acknowledges that when a discrepancy occurs, further reflection is important. For this reason, Riley was prompted during her reflective interview to explain the absence of the in-class activities that she had discussed previously. Riley gave three main reasons that she has not been able to incorporate collaboration between students during her classes. First, Riley's class was held virtually, and low attendance has been an issue. Second, she explained that

breakout rooms have not been successful because students log in to class but are not actually at their computers. She elaborated that she has assigned students to breakout rooms where only one student is actually actively at their computer which defeats the purpose of the collaboration time. Third, Riley explained that polling has not worked very well because of the difficulties in typing math into the available polling software. Again, this discrepancy between espoused beliefs and current theories-in-use can be explained by external factors that force the instructor to change practice (Hora & Anderson, 2012; Li, 2013; Norton et al., 2005). Even so, at the end of the reflective interview, Riley emphasized her wishes to create better collaboration opportunities in her future classes whether she continues to teach remotely or returns to teaching in person. This suggests Riley has a strong desire to create consistency between her teaching beliefs (espoused theories) and her teaching practices (theories-in-use).

Taylor

Taylor taught Precalculus I courses for the semester of this study. Her courses were held in person. Taylor's score on the TPI was 21 out of 69. This was the lowest TPI score among the qualitative participants. In Taylor's responses to the TBI interview questions, three responses were coded as *Traditional* and four responses were coded as *Instructional*. Taylor's most frequent teaching practices during observations that were exhibited in more than 80% of the coding intervals were *lecture*, using *multimedia*, and *working out problems*.

All of Taylor's responses to the TBI questions were on the teacher-centered side of the teacher-centered to student-centered beliefs continuum. This strongly indicates that Taylor holds teacher-centered beliefs. Taylor's responses in the initial interview primarily focused on content delivery. She emphasized providing students with as many resources as possible which include videos of lecture and the notes that she goes over in class. Taylor's teacher-centered beliefs are

consistent with her lower TPI score that indicates she uses a small amount of research-based teaching practices. Moreover, Taylor scored 2 out of 15 on the In-Class Features and Activities section of the TPI which further evidences her utilization of direct instruction.

Classroom observations substantiated that Taylor is consistent between her teacher-centered beliefs (espoused theories) and her teaching practices (theories-in-use). During classroom observations Taylor *lectured* in 100% of the coding intervals. She also *worked out problems* during 98% of the coding intervals. Taylor did not pose any questions for students to answer during any of the coding intervals. She provided direct instruction by working examples at the board throughout the observations. However, Taylor did end each class early so students could ask individual questions at the end of class if they wished.

Taylor indicated on the TPI that she did pause during instruction to ask students for questions. However, this behavior was not observed. As suggested by Li's (2013) research, Taylor was prompted during her reflective interview to discuss this discrepancy. Taylor explained that she is aware that she does not ask her students many questions. She added that she wants to ensure that she gets through all of her material so the students can see as many examples as possible explained. She continued that the pauses she provides are primarily to allow students to write down the notes from the board. This suggests that Taylor was not inconsistent between her self-report on the TPI and her classroom practices but, instead, that she had interpreted the question on the TPI differently than the researcher. Speer (2005; 2008) contended that some inconsistencies between espoused beliefs and theories-in-use may actually be in alignment once shared understanding is achieved.

Taylor demonstrated a high level of consistency between her teacher-centered beliefs and content-centered teaching practices. So, excerpts from her reflective interview that describe some

of her reasons for her methods are provided below. Exploring this focus on teacher-centered beliefs and practice is especially important in order to create understanding as to why more modern research-based practices are not being used (Oleson & Hora, 2013).

In the reflective interview, Taylor addressed some of her reasons for using direct instruction. First, she stated:

> I just started teaching direct instruction this way, I think, because that's mostly how I've been taught and that's kind of why I ended up using this teaching method. And I am sure that probably applies to a lot of other teachers too. That's what their learning experience was.

Next, Taylor explained she is comfortable at the board, because it makes her feel like she is doing something. She also described her negative experiences as a student with group work, and stated:

> So, I think maybe that is why I tend not do as much group work, even though I feel, even though all of the research says that you should be doing that. Because people learn better or can learn better that way. But I also think that there's some people that may learn best by lecture style too.

However, during the reflective interview Taylor's conversation shifted toward the possibility of using student-centered practices. Taylor explained that in the past she provided students time to work problems in class while she walked around. She stated that she wants to implement that practice again in future classes. She also stated that perhaps it would be worth spending class time to give students an opportunity to attempt problems on their own, even if it meant that she did not explain as many examples to the class.

According to Nghia (2017), personal motivators such as desire to improve teaching skills affect instructors' transfer of teaching beliefs to teaching practices. Later in the interview, Taylor shared her opinions about changing teaching practices:

> One thing I do want to say is I think as educators a lot of us sometimes are afraid to do new stuff. I know for me sometimes I can hesitate a little bit. In the past, even for me, it's taken me a while to try new things… So I think some of these things, I need to be personally stretched a little bit… I think it is important to have the attitude to want to change because ultimately, we want to try to see what method is best for our students to use. And I think if there's new tools that are out there, I think we need to be willing to try some new things. But I admit that sometimes I can be complacent. It's kind of like, well if it ain't broke don't fix it. But then there might be something, it might be working, but there might be something that might be working even better. So, I think it is important as educators that we need to be open.

Taylor's statements above provide insight into why she implements the knowledge transmission model of instruction (Bailey et al., 2015; Edwards et al. 2015; Grubb, 1999; Grubb & Gabriner, 2013; Hora, 2016; Hora & Ferrare, 2013; Kember & Gow, 1994). Oleson and Hora (2013) explored the general sentiment, that "teachers teach the way they were taught." Although, this maxim does reflect Taylor's primary reason for her teaching practices, Oleson and Hora (2013) concluded in their research, "The evidence shows that instruction decision making is far more complex than [the] phrase suggests, and that modeling and imitation of one's own teachers is not the only type of experience that shapes faculty teaching practice" (p 40-41). However, Taylor's feedback supports prior research that pedagogical knowledge and pedagogical content

knowledge is inadequate for collegiate faculty (Brown et al., 2006; Ellis, 2014; Gandhi-Lee et al. 2015; Kane et al. 2002; Reys et al, 2009; Speer & Hald, 2008; Yow et al., 2016).

Harlow

Harlow taught Precalculus I courses for the semester of this study. Her courses were held remotely using a virtual platform. Harlow's TPI score was 24 out of 69 which was in the low range of scores for the qualitative participants. In Harlow's responses to the TBI interview questions, four responses were coded as *Traditional* and three responses were coded as *Instructional*. Harlow's most frequent teaching practices that occurred in more than 80% of the observation coding intervals were *lecture* and using *multimedia*.

All of Harlow's responses on to the TBI questions were coded on the teacher-centered side of the teacher-centered to student-centered beliefs continuum. Additionally, Harlow's score on the TPI was low which indicates a low use of research based-teaching practices. Both Harlow's initial interview responses and her self-reported practices from the TPI signify that Harlow primarily holds teacher-centered beliefs. In the initial interview, Harlow's responses emphasized her focus on content delivery, ensuring that she teaches all of the required topics for the course and that students complete homework and practice doing math frequently. Harlow described that it was important for students to ask questions to create understanding and to complete homework without blindly copying an example. Although Harlow expressed the importance of student practice, she does not provide opportunities for students to practice in the class setting. Harlow only described students completing practice problems outside of class in her first interview, and this was confirmed by classroom observations. This was also indicated by her score of 1 out of 15 in the In-Class Features and Activities section of the TPI.

Classroom observations demonstrated alignment between Harlow's teacher-centered beliefs (espoused theories) and her content-centered teaching practices (theories-in-use). Harlow spent a large portion of all coding intervals *lecturing*. Harlow did create some student engagement by posing questions to the class. She asked at least one of each type of question (*comprehension questions*, *display algorithmic questions*, *rhetorical questions*, and *display conceptual questions*) in 30% or more of the coding intervals. Furthermore, Harlow created *whole-class discussion* with her students in 62% of the coding intervals. Yet, many of the questions had simple answers and discussion input from students was brief. Harlow utilized the knowledge transmission model in her classroom where she provided direct instruction and students' only opportunities to test understanding occurred in answering simple questions (Bailey et al., 2015; Edwards et al. 2015; Grubb, 1999; Grubb & Gabriner, 2013; Hora, 2016; Hora & Ferrare, 2013; Kember & Gow, 1994).

Similar to Taylor, Harlow was consistent between her espoused theories and theories-in-use which were both teacher-centered. Again, it is important to explore why Harlow does not adopt more modern research-based practices (Oleson & Hora, 2013). In both Harlow's initial and reflective interview she was adamant in her perspective that collaborative group style work was unproductive in the classroom. In the initial interview Harlow described several reasons for her disapproval. First, Harlow expressed that too much time was wasted in the classes that she had observed where group work was taking place. Second, she noticed that several students were not engaged and seemed to be waiting for the class to be over. Third, she felt that the students did not actually enjoy group work. Last, she expressed concern that she would run out of time to teach all of the required material if she implemented group work.

In the reflective interview, Harlow reiterated these concerns. She also described that in her recent observations (during the semester of this study) she felt that the students were bored, and the application style lesson she viewed moved too slowly. Additionally, Harlow explained that during these observations, she feels that her own teaching practices are superior. She stated, "As a matter fact, there were some things that I thought, hmm I could have done that a lot better… A lot of times I am going well I am doing that better." In this case, Harlow exemplifies Nespor's (1987) belief characteristic of non-consensuality which describes beliefs as being static and difficult to change.

The concerns that Harlow described in the context of group work and in her other responses during both interviews illustrated Harlow's prioritization of content. Harlow's statements demonstrated that her primary goal was to ensure that she taught all of the required material. Harlow expressed her worry that she does not want to send her students to their following math courses underprepared. She said, "Pretty much I go on because I have to go on… Because if it came to some students, you could spend an entire week on a topic that requires ten minutes." This supports prior findings from Mesa and colleagues (2014) that noted the main goal for many instructors was covering content, even if the students could not keep up.

Casey

Casey taught College Algebra courses for the semester of this study. His courses were held in person. Casey's score on the TPI was 36 out of 69 which was in the high range of scores among the qualitative participants. In Casey's responses to the TBI interview questions, one response was coded as *Traditional*, one response was coded as *Instructional*, two responses were coded as *Transitional*, two responses were coded as *Emerging Constructivist*, and one response

was coded as *Experienced Constructivist*. Casey did not perform any teaching practices for more than 80% of the coding intervals during observations.

At least one of Casey's responses was coded into each of the five categories on the teacher-centered to student-centered beliefs continuum. Two of his responses were in the center of the spectrum, two were on the teacher-centered side of the spectrum, and three were on the student-centered side of the spectrum. This suggests that Casey's teaching beliefs tend to be more student-centered. During his initial interview, Casey emphasized student interaction through discourse. He also stressed establishing opportunities in class to view student work and question student thinking. This is consistent with Casey's higher score on the TPI that indicates he uses several research-based teaching practices. Additionally, Casey earned at least two-thirds of the points possible in the following sections of the TPI: In-Class Features and Activities, Assignments, and Feedback and Testing. His scores in these sections further indicate that his self-reported practices are consistent with his teaching beliefs (espoused theories).

Casey's classroom observations further demonstrated alignment between his espoused theories (teaching beliefs) and his theories-in-use (teaching practices). Of the qualitative participants, Casey demonstrated the most frequent use of a large variety of teaching practices. The practices he used in at least 50% or more of the coding intervals included *lecture*, *whole-class discussion*, asking *comprehension questions*, using *online techniques*, using *multimedia*, *working out problems*, and asking *display algorithmic questions*. Furthermore, Casey *lectured* in less coding intervals than any of the other qualitative participants. His variety of teaching practices paired with his relatively low use of *lecture* illustrated Casey's propensity for student-centered teaching practices. Casey implemented *whole-class discussion* almost as frequently as *lecture* which further indicates that Casey was successful in generating student interactions.

As suggested by Hora and Anderson (2012), it is important to identify conditions that lead instructors to apply student-centered teaching methods. Since Casey demonstrated use of several research-based practices, his espoused theories from the initial and reflective interviews were explored further. In his initial interview, Casey described his motivators for using a flipped classroom. He explained that students come to class with a baseline understanding, so class time can really be used to focus on student understanding. Other valuable aspects he described were that he no longer runs out of time to cover content and that he is able to answer all of his students' questions.

In both interviews, Casey stressed that students should be continuously assessing their own understanding; this includes reviewing definitions and theorems, practicing problems, referencing their notes, and then testing themselves by completing problems without their notes. He stated that students should also be using this process to find their misunderstandings. Afterwards, the students should see him in office hours or during class work time to address those misunderstandings. In the reflective interview Casey elaborated:

> I just really feel like it is a struggle to get them to really understand how much time they really need to put in on their own. I mean, nobody wants to do that…And [I] tell them that when I was first learning that material or just other material in my studies, especially math in particular, that it didn't just always come easy to me. I did all of the things that I am telling them that they need to be doing. I did do these exercises over and over and over again. And it took a ton of time… You never know how they are really studying, that's the thing. But hopefully they're really listening and taking to heart my suggestions.

Casey's explanations suggest that his biggest motivator for applying his teaching practices (theories-in-use) is his belief (espoused theory) that students need to be actively practicing math in order to learn it.

Addison

Addison taught College Algebra courses for the semester of this study. His courses were held remotely using a virtual platform. Addison's score on the TPI was 29 out of 69 which was in the middle range of scores among the qualitative participants. In Addison's responses to the TBI questions, one response was coded as *Traditional*, four responses were coded as *Instructional*, one response was coded as *Transitional*, and one response was coded as *Emerging Constructivist*. Addison's most frequent teaching practices exhibited during observations that occurred in more than 80% of the coding intervals were *lecture*, using *multimedia*, and *working out problems*.

Addison's responses in his initial interview were primarily teacher-centered. Five of his responses were coded on the teacher-centered side of the student-centered to teacher-centered beliefs continuum. One of his responses was in the center of the spectrum, and one of his responses was on the student-centered side of the spectrum. This suggests that Addison primarily holds teacher-centered beliefs. Many of Addison's responses illustrated his focus on content delivery which is a teacher-centered behavior. Yet, Addison described posing questions as a method to create student discussion. He also stated that he provides students with class time where they can attempt problems prior to his explanation for solving the problem. He employs this method to generate active participation from his students.

Addison's teacher-centered responses in the initial interview are consistent with his lower TPI score that suggests he implements a small amount of research-based practices. Addison's

score for the In-Class Features and Activities section of the TPI was 5 out of 15. This self-report of his teaching practices also aligns with Addison's teacher-centered responses in the first interview. Furthermore, Addison's higher scores on the TPI were in the Assignment section and the Feedback and Testing section which may signify that the research-based practices that he does implement occur outside of class time.

Classroom observations mainly illustrated alignment between Addison's teacher-centered beliefs (espoused theories) and his teaching practices (theories-in-use). Addison's most frequent teaching behavior was *lecture* which is consistent with Addison's focus on content delivery. Even so, Addison did exhibit some student-centered practices such *whole-class discussion* which occurred in 76% of the coding intervals and *desk-work* which occurred in 40% of the coding intervals. These teaching practices (theories-in-use) align with Addison's student-centered (espoused theories) in his first interview responses. As discussed in his interview responses, Addison did pose questions to his students. He asked *comprehension questions* in 62% of the coding intervals, *display algorithmic questions* in 42% of the coding intervals, and *display conceptual questions* in 29% of the coding intervals. These teaching practices (theories-in-use) align with Addison's student-centered responses (espoused theories) in the TBI interview. Although these behaviors did occur, the lower frequency of these teaching practices maintain consistency with Addison's tendency to be more teacher-centered in his espoused theories.

One discrepancy was Addison's implementation of group projects which is generally described as a student-centered practice. Addison indicated on the TPI that he assigned group projects. However, he did not discuss them in the initial interview and group work was not seen in class observations. So, Addison was asked to elaborate about his utilization of group work during his reflective interview. He explained that he does not assign group projects in his

courses, unless he is required to by the department. He described that many of the students struggle to collaborate and do not put effort into the projects. Addison also stated that they are difficult to grade. However, Addison admitted that he does see an improvement in understanding for the students who do work hard on the projects. So, the group projects are required rather than Addison's own preference. Thus, it is reasonable that the student-centered practice of assigning collaborative projects is somewhat inconsistent with his tendency to teacher-centered beliefs. Similar to Finn, Addison's inconsistency in this case demonstrates a compromise in espoused theory and theory-in-use because of the department requirements (Hora & Anderson, 2012; Norton et al., 2005).

Addison seemed to vary between teacher-centered beliefs and practices and student-centered beliefs and practice. For the most part, Addison's student-centered beliefs were supported with student-centered behaviors and his teacher-centered beliefs were supported by teacher-centered practices. So, Addison displayed alignment between most of his espoused theories and theories-in-use. In his initial and reflective interviews, Addison did share thoughts about creating student engagement, supporting his students with resources, and accounting for student feedback which all indicate student-centered beliefs. Yet, many of Addison's responses about teaching decisions were still teacher-centered. Furthermore, Addison's TPI scores and his predominant classroom practices that were observed illustrate teacher-centered beliefs and practices. Oleson and Hora (2013) described similar results where tacit views of teaching and habitual teaching practices dominated classroom practices more than discussed beliefs.

Table 23 contains a summary of the results for each participant based on the information described in the prior paragraphs. The overall score from the TPI is provided. The number after each TBI code is the number of times each participant received that code. Codes from the

classroom observation protocol that occurred in at least half of the coding intervals are provided. Also, included is a description of what was aligned or not aligned from the TPI, TBI codes, and classroom observations.

Table 23

Summary of Results

Instructor	TPI Score	TBI Codes	Observation Practices >0.50 Relative Frequency	Alignment
Finn	32 of 69	Traditional: 2 Instructional: 3 Emerging Constructivist: 2	Lecture, Multimedia, Comprehension question, Worked out problems, Display conceptual question, Display algorithmic question, Receive/memorize information, Understanding problem solving, Connecting to the real world, Overhead projector/Elmo, Pointers, Demonstration Equipment	Aligned: • Lecture time • Limited feedback to students • Questions for student input • Teacher-directed style Not Aligned: • Viewing student work during class • Group Assignments
Blair	39 of 69	Traditional: 1 Transitional: 4 Emerging Constructivist: 2	Lecture, Multimedia, Desk work, Worked out problems, Receive/memorize information, Connecting to the real world, Understanding problem solving, Computer and slides, Digital tablet, Miscellaneous object	Aligned: • Students doing projects • Student choice • Learning concepts • Relevant Math • Time for students to think Not Aligned: • Lecture time • Class group work
Riley	35 of 69	Traditional: 2 Instructional: 1 Transitional: 1 Emerging Constructivist: 2 Experienced Constructivist: 1	Lecture, Multimedia, Whole-class discussion, Worked out problems, Receive/memorize information, Understanding problem solving, Computer and slides, Digital tablet	Aligned: • Lecture time • Ideas for student interaction • Listens to student feedback • Class discussion Not Aligned: • Class group work
Taylor	21 of 69	Traditional: 3 Instructional: 4	Lecture, Multimedia, Worked out problems, Receive/memorize information, Blackboard/ whiteboard, Pointers	Aligned: • Lecture time • Traditional assessment • Limited communication • Providing examples • Teacher-centered Not Aligned: • Pauses during instruction
Harlow	24 of 69	Traditional: 4 Instructional: 3	Lecture, Multimedia, Whole-class discussion, Worked out problems, Receive/memorize information, Integrating ideas, Digital tablet	Aligned: • Lecture time • Focus on content delivery • No class activities • Limited student interaction • Content Driven Not Aligned: • None
Casey	36 of 69	Traditional: 1 Instructional: 1 Transitional: 2 Emerging Constructivist: 2 Experienced Constructivist: 1	Lecture, Whole-class discussion, Comprehension question, Online techniques, Multimedia, Worked out problems, Display algorithmic question, Receive/memorize information, Understanding problem solving, Overhead projector/Elmo, Blackboard/ whiteboard	Aligned: • Lecture time • Students self-evaluate • Group work • Class discussions • Department materials • Trying new methods • Student-centered approach Not Aligned: • None
Addison	29 of 69	Traditional: 1 Instructional: 4 Transitional: 1 Emerging Constructivist: 1	Lecture, Multimedia, Worked out problems, Whole-class discussion, comprehension question, Receive/memorize information, Understanding problem solving, Computer and slides, Digital tablet	Aligned: • Lecture time • Assignments to check for understanding • Students working together • Posed questions to create discussion Not Aligned: • Group assignments

Comparisons Between Qualitative Participants

Most of the qualitative participants were consistent between self-reporting of their time spent lecturing and their lecture times noted during observations. Harlow, Taylor, Addison, and Finn all reported that they lectured 80% to 100% of class time, and classroom observations confirmed this practice. Furthermore, Harlow and Taylor were in the lowest grouping of TPI scores, and Addison and Finn were in the middle grouping of TPI scores. All four instructors scored low in the In-Class Features and Activities section of the TPI which corresponds to their higher proportion of time spent lecturing.

Riley self-reported lecturing 60% to 80% of class time. Classroom observations of Riley showed that she *lectured* during all of the coding intervals; however, *lecture* did not occur for the entirety of the interval, so it is reasonable that Riley's self-report was consistent with the observation. Similarly, Casey reported that his time spent lecturing was 40% to 60% of class time, but in observations he *lectured* for some portion of 76% of the intervals. Yet, he did not *lecture* during the whole time period in any of the intervals, so his self-report is reasonable. Casey and Riley both had two of the highest TPI scores of the qualitative participants and they both scored 10 out of 15 in the In-Class Features and Activities section of the TPI. Lastly, Blair reported that she lectures 40% to 60% of class time, but observations indicated that she *lectured* during some portion of 98% of the coding intervals. Since this is much higher than her self-report, Blair was identified as inconsistent between her self-report and observation data. Blair had the highest score on the TPI of the qualitative participants, but her score for the In-Class Activities and Features section of the TPI was 7 out of 15 points which may correspond to her higher proportion of lecture than she self-reported.

Student communication and feedback to students was a second area in which instructors were mostly consistent between their self-reports, interview discussions, and classroom observations. Taylor and Harlow both employ direct instruction in their classrooms, so student communication is limited to emails or conversations that occur after class. This was consistent with their classroom observations. Harlow created some classroom discussions by posing questions, but student response was limited. Additionally, Taylor and Harlow both provide students feedback in the form of graded assignments and assessments. These behaviors are consistent with their teacher-centered responses on the TBI as well as their low scores in the Feedback and Testing section of the TPI.

Finn and Addison both discussed using questions to create student communication in their classrooms. This practice was confirmed during classroom observations where Finn asked *comprehension questions*, *display conceptual questions*, and *display algorithmic questions* in more than 50% of the coding intervals. Similarly, Addison's classroom observations showed that he asked *comprehension questions* and *whole-class discussions* occurred in over 50% of the coding intervals. However, Finn's feedback to students primarily consisted of graded assignments and exams instead of communication with students. Addison's feedback to students entailed graded assignments and exams, while also including encouragement to meet one-on-one. Finn and Addison both scored more than two-thirds of the points in the Feedback and Testing section of the TPI. Moreover, this is aligned with their TBI responses that were primarily teacher-centered with intermittent student-centered responses.

Blair, Riley, and Casey all expressed the importance of student communication in their classrooms. Blair specifically discussed using projects to give students choice in their learning and to create assignments that highlighted student thinking and understanding. In Blair's

classroom observations she made *connections to the real world* in over 50% of the coding intervals. She also provided her students time to work problems with class discussions following work time. Riley specifically discussed creating student engagement through *whole-class discussions* which was also observed in 77% of the coding intervals during classroom observations. Casey described prioritizing student questions and generating discussion during his classes in the interviews. This was consistent with Casey's classroom observations in which *whole-class discussion* occurred 69% of the coding intervals. Additionally, Casey asked *comprehension questions* and *display algorithmic questions* in over 50% of the coding intervals. In TPI responses, all three instructors indicated providing graded assignments and exams as feedback to students. Both Casey and Blair marked on the TPI that students are encouraged to meet with them individually. Additionally, Casey indicated on the TPI that he allows students to redo work after they have received feedback. All of these observation behaviors further align with all three participants' higher occurrences of student-centered responses on the TBI as well as their higher scores on the TPI.

Several of the instructors were inconsistent with their responses about student activities in class and their use of group work. Both Blair and Riley discussed creating student interaction during their class setting. Blair specifically stated that she wished to create learning opportunities outside of lecture. However, student activities were not observed in Blair's classroom. Riley described several methods for creating student interaction in her initial interview. Yet, many of these methods for student interaction were not observed in Riley's classroom. Both instructors seemed to have difficulty creating student-centered interactions in their remote teaching environments, despite their indicated beliefs that student interaction is important.

Casey was consistent in both his responses in the TBI where he discussed creating student interactions and in his classroom observations where class discussion and student interactions with one another were observed. Moreover, *whole-class discussion* occurred during almost as many coding intervals as *lecture* occurred. This observation further aligns with Casey's high scores in the In-Class Features and Activities section of the TPI and his predominantly student-centered responses to the TBI interview questions.

Finn and Addison both indicated on their TPI responses that they assigned specific group work assignments and that students were encouraged to collaborate with one another. However, both Finn and Addison described frustrations with group projects during their reflective interviews. Both instructors assign group projects because of departmental requirements, rather than their own preference. Addison explained during his reflective interview that he does not assign group work in his courses that do not require it. So, in this case both instructors' actions are inconsistent with their beliefs.

Taylor and Harlow were both consistent in their teacher-centered style that does not incorporate student activities or group work. Each instructor scored on the lower end of the TPI scores. Additionally, each instructor scored less than 15% for the In-Class Features and Activities section of the TPI. This aligns with each of their responses in the TBI, where all responses were either *Traditional* or *Instructional* to all of the interview questions. Moreover, both instructors spent their class time presenting content through direct instruction. These aspects further indicate the alignment between each instructor's teacher-centered beliefs and content-centered teaching practices.

Discussion

Blair, Riley, and Casey had the highest scores of the seven participants on the TPI, the most student-centered responses from the TBI, and their beliefs impacted the practices they emphasized in their classes. Blair tries to ensure that students have multiple ways of demonstrating understanding. Blair has implemented mini-projects and projects in her classes. She also views student homework before class meetings to check for common mistakes so she can review those common mistakes during class. Blair focuses on students understanding concepts. Riley emphasized the importance of students discussing and doing math. If Riley is not able to answer all questions or get through all the material in a class, she will send students a video explaining the rest of the material. By sending out videos of examples, Riley is able to answer student questions and review missing pre-requisite skills while maintaining her set schedule. Riley is also willing to try new ideas in her teaching which include working to integrate technology. Casey focuses on student discussion and uses videos in his teaching as well. Students come to class with a baseline understanding developed by pre-made materials that Casey has created and uploaded on the course website. Then, during class time, students can ask questions and get instructor help on the concepts that they do not understand.

For these three participants, a belief in student discourse, representations, feedback from students, and providing resources to students were important in how they structured their classes. Research has noted that teaching in college mathematics classrooms often uses a knowledge transmission model: a method of teaching which is teacher-centered where content focused information is provided to students without an opportunity to practice it (Bailey et al., 2015; Edwards et al. 2015; Grubb & Gabriner, 2013; Hora, 2016; Hora & Ferrare, 2013). The use of videos for instruction and other resources provided to students can be one way to allow for more

student discourse and working of problems during the class in order to get immediate feedback. Duckworth (2016) notes the importance of deliberate practice for improvement. This includes four components: a clearly defined goal, full concentration and effort, immediate and informative feedback, and repetition with reflection and refinement. By incorporating class time for students to work problems, students are able to receive immediate feedback which may improve the practice that they do outside of class. Analyzing homework before class for common mistakes and discussing those mistakes is another way to provide informative feedback.

Both Finn and Addison were in the middle grouping of TPI scores. In their case, they both tended toward teacher-centered beliefs and applied teacher-centered practices. Yet, both instructors did discuss some student-centered beliefs such as creating student interactions by posing questions or viewing student work. Addison stressed that active participation is important but primarily lectured. Finn described walking around his classroom to view student work but did not exhibit this practice during classroom observations. Both instructors struggled to employ more student-centered practices in their classrooms. Assen (2016) described that holding particular beliefs did not necessarily invoke a change in practice. Furthermore, instructors tend to have difficulty using student-centered methods over content-centered methods (Assen, 2016). Once a change in beliefs has occurred, instructors may need more training and support before implementation of new practices will be successful. Research has previously noted lack of pedagogical training as a problem for collegiate faculty (Gandhi-Lee et al., 2015). Moreover, prior research has suggested training in pedagogical knowledge as a potential method for supporting collegiate faculty (Ellis, 2014; Reys et al, 2009; Speer & Hald, 2008; Yow et al., 2016).

A main research-based practice that both Finn and Addison employed was the assignment of group projects. However, both instructors acknowledged their dissatisfaction with this departmental required coursework. In this case, a change in practice has occurred before a change in belief due to external factors creating an inconsistency between espoused beliefs and teaching practice. Again, the instructors are making compromises because of their academic setting (Hora & Anderson, 2012; Norton et al., 2005). After voicing frustrations with the projects, both instructors did concede that there were some benefits for students such as creating stronger conceptual understanding. Since teaching practices are affected by teaching beliefs (Addy et al, 2015; Ernest 1994; Holland, 2018; Pajares, 1992; Philipp, 2007), implementation of this student-centered practice may be improved if the instructor's beliefs were aligned with that practice.

Both Taylor and Harlow were in the lowest grouping of TPI scores. Both instructors discussed teacher-centered beliefs (espoused theories) and demonstrated teacher-centered practices (theories-in-use). As described by prior research, these instructors applied the knowledge transmission model for teaching (Bailey et al., 2015; Edwards et al. 2015; Grubb & Gabriner, 2013; Hora, 2016; Hora & Ferrare, 2013). Aligning with results described by Mesa et al. (2014), these two instructors described and displayed a primary goal which was to ensure all required content was presented regardless of the students understanding of the topic. Martin and colleagues (2000) explained that when instructors are focused on a particular topic there is close association between teaching objectives and teaching practices. Taylor and Harlow both exhibited strong alignment between their espoused theories and their theories-in-use which may be explained by their profound focus on content.

Research has suggested that teachers make compromises between their beliefs and enacted teaching methods based on different influences (Norton et al., 2005). One of the influences during this study was the COVID-19 pandemic. The effects of moving to virtual classes was a theme that emerged from the participants. It was more difficult for the participants to implement their normal teaching practices which made instruction more teacher-centered with less feedback and interaction. Blair noted that if she were teaching in person, she would be able to create more opportunities for student interaction. Students' attention and engagement was also harder to gauge with online learning, as many students did not have their cameras on and some students would not participate. Taylor explained that prior to the pandemic she used to give test reviews and walk around the room to see individual student work. She explained that she could discuss and correct individual work with the students. Addison also noted that this is what he would do for in-person learning.

Speer (2008) contended that inconsistencies between teaching beliefs and teaching practices may be justified. Furthermore, Speer (2008) explained that instructors apply teaching actions based on collections of beliefs rather than a singular belief. In this study, three of seven qualitative participants were consistent between their beliefs and practice. In the case of the remaining four participants, the inconsistencies that were recognized could be explained. Most frequently a compromise was being made between departmental requirements or other external factors, such as the remote teaching environment (Hora & Anderson, 2012; Norton et al., 2005). It is arguable that the instructors may still be following certain beliefs within a collection of beliefs. For example, an instructor may believe that student-centered practices are important, yet they also believe following the content as outlined by the department is an integral part of their job. Thus, making a compromise between beliefs within their own collection as well as making

compromises between their teaching actions to ensure they are completing both actions to some extent are present in some instructors' experiences. Furthermore, Argyris (1995) described mismatches between espoused theories and theories-in-use as being systematic. Casey was primarily student-centered in his beliefs and actions. However, he did provide two teacher-centered responses in the TBI interview, which were related to departmental requirements for content. This may indicate that Casey is methodically following beliefs within his existing collection of teaching beliefs.

Implications

This study has shown that the collegiate math instructors interviewed and observed were mostly consistent between their espoused theories and their theories-in-use. When an inconsistency did occur, the primary reasons for the inconsistency were to due contextual factors. This supports previous findings that teaching norms affect instructors and their practices (Hora & Anderson, 2012), and those instructors are making teaching decisions based on compromises between their teaching beliefs and teaching practices (Gandhi-Lee et al., 2015).

Previous research noted that it is unknown how well faculty implement research-based teaching practices (Hora, 2016). This research has shown that the teaching practices that were self-reported using the Teaching Practices Inventory (TPI; Carl Wieman Science Education Initiative, 2018; Wieman & Gilbert, 2014) were largely consistent with teaching beliefs described through responses in the Teaching Beliefs Interview (TBI; Luft & Roehrig, 2007) and observed classroom practices. This suggests that the TPI could be used as a reliable instrument to further explore collegiate math faculty use of research-based practices.

The use of multiple methods in this study provided a rich description of the qualitative participants' reasons for applying the teaching practices they did. As suggested by previous

research, this study indicates that knowledge of teaching beliefs does help explain reasons for instructors' enacted teaching practices (Ernest, 1994; Hora & Ferrare, 2013; Kane et al., 2002; Luft & Roehrig, 2007). Furthermore, the use of reflective interviews (Speer 2005; Speer 2008; Li, 2013) was integral in understanding discrepancies between espoused beliefs and theories-in-use. This research study sets a precedent for the use of multiple methods, especially the use of reflective interviewing, as a valuable tool for better understanding the reasons faculty implement their chosen teaching practices and the connection of those practices to their espoused beliefs.

Hora and Anderson (2012) claim "one of the core problems facing pedagogical reform is to identify the factors that lead faculty to adopt interactive teaching methods" (p.586). From this study, two main factors were found that should be considered in order to help instructors adopt more student-centered teaching methods. Satisfaction with current teaching practices was a theme that affected whether participants were willing to try different teaching methods in their classes. Rogers' (1995) diffusion of innovation theory describes how people can adapt to a new idea. The first two steps are knowledge and persuasion. For teachers to try a new idea they need to gain information about it and believe that it would be beneficial to implement. A related factor is the time for teachers to do this. One way that this could be done is requiring meetings between teachers who teach the same classes as part of the teachers' job in order to encourage collaboration and improvement of courses. As was seen in my study, departmental guidelines can encourage student-centered teaching practices.

The other main factor that was mentioned by some participants was their fear of new teaching methods leading to poor results. A few of the participants noted this and did not want to try something new if they were not sure they could implement it well. Gradual implementation of new ideas paired with support and feedback from colleagues can help when trying new ideas.

Changes in classroom practice such as teaching using Model-Eliciting Activities and increased pedagogical knowledge may influence instructor beliefs, leading to more research-based teaching practices being enacted in college classrooms (Addy et al., 2015; Kensington-Miller et al., 2012; Moore et al., 2015; Oleson & Hora, 2014). Technology and resources available for teaching mathematics continue to change, and it is important to have a growth mindset for teaching to be willing to improve as instructors want their students to improve in their learning.

Limitations

Generalizability of this study is limited since the sample size is small, especially in regard to the quantitative data results discussed in the study. Also, the researcher performed all the scoring of the quantitative surveys, coding of the TBI interview results, and classroom observations, so there is no inter-rater reliability for the data analysis of this study. Although multiple types of data were collected to mitigate reliability issues in the study, the Teaching Practices Inventory for the quantitative data collection was self-reported. This may lead to inaccuracy in reporting or misinterpretations between the researcher's intent and the participant's understanding of the questions. Lastly, there were only 10 survey responses when the researcher had to move forward in choosing qualitative participants. So, the range of scores between qualitative participants was small.

However, the study did have a rich description of teaching beliefs and teaching practices for the seven qualitative participants using multiple measures. Reflective interviews provided the researcher an opportunity to clarify any misunderstandings in the self-reported data and discuss discrepancies between interview responses and classroom observations. Furthermore, the reflective interviews allowed for member checking of the initial interview results. Additionally, the researcher had four meetings (initial interview and three classroom observations) with each

qualitative participant prior to the reflective interview. This may have increased comfortability for the qualitative participants, so they were more willing to discuss their personal beliefs with the researcher.

Recommendations for Future Research

It is important that mathematics instructors use equitable teaching practices and reflect on how their beliefs and practices are focused on providing students the best chance to be successful. Bartell et al. (2017) describes nine equitable teaching practices. A few of these include drawing on students' funds of knowledge, establishing classroom norms for participation, positioning students as capable, pressing for academic success, attending to students' mathematical thinking, and attending explicitly to race and culture. The instructors in this study did make connections to some of these practices in working to build students' mathematical confidence, getting to know their students, encouraging them, using relevant problems, and building on students' mathematical thinking. The participants also had the opportunity to reflect on their beliefs and practices for how students can learn best. Future research could focus more specifically on how teaching beliefs of post-secondary mathematics faculty are aligned with equitable teaching practices. Future research can also include more information about the instructors' backgrounds and teaching experience and how this may impact their beliefs and practices.

Future research should explore these relationships on a larger scale. While this study offers a basis for the use of multiple methods to describe relationships between teaching beliefs and teaching practices of mathematics faculty, it is important to confirm results on a larger scale. Performing this study with a larger sample of quantitative participants would allow for a more diverse subsample of qualitative participants while creating better generalizability. It is important

to continue this exploration and make connections between beliefs and practice so pedagogical changes at the college level have better success and implementation.

Another future study could explore these relationships using similar methods as this study, followed by an active intervention. Since teaching beliefs and teaching practices are strongly interconnected, it is important to explore the success rate of an intervention that aims to influence instructor beliefs and instructor practice concurrently. It may be beneficial to work with a small number of participants so the intervention could be tailored to change more specific teaching beliefs and teaching practices. This type of study could provide evidence that pedagogical reform through professional development can support a shift in teaching beliefs and a shift in teaching practices simultaneously, especially since it has been identified that instructors are a crucial aspect of educational reforms (Moore et al., 2015).

Appendix A

Teaching Practices Inventory

This inventory was created by devising a list of the various types of teaching practices that are commonly mentioned in the literature. We recognize that these practices are not applicable to every course, and any particular course would likely use only a subset of these practices.

Places have been added where you can make additions and comments and we welcome your feedback.

It should take only about 10 minutes to fill out this inventory.

Please fill out the inventory for the current or last semester. Lecture sections only.

Contact information and course information

Name:
Email:
Main course taught:
Format you usually teach in (in person or online):

I. Course information provided to students via hard copy or course webpage. (check all that occurred in your course)

- ❑ List of topics to be covered
- ❑ List of topic-specific competencies (skills, expertise, …) students should achieve (what students should be able to do)
- ❑ List of competencies that are not topic related (critical thinking, problem solving, …)
- ❑ Affective goals – changing students' attitudes and beliefs (interest, motivation, relevance, beliefs about their competencies, how to master the material)
- ❑ Other (please specify) _____

II. Supporting materials provided to students (check all that occurred in your course)

- ❑ Student wikis or discussion boards with little or no contribution from you.
- ❑ Student wikis or discussion boards with significant contribution from you or TA.
- ❑ Solutions to homework assignments
- ❑ Worked examples (text or another format)
- ❑ Practice or previous year's exams
- ❑ Animations, video clips, or simulations related to course material
- ❑ Lecture notes or course PowerPoint presentations (partial/skeletal or complete)
- ❑ Other instructor selected notes or supporting materials, etc.
- ❑ Articles from related academic literature
- ❑ Examples of exemplary papers or large projects

- ❑ Grading rubrics for papers or large projects
- ❑ Other (please specify) _____

III. In-class features and activities

A. Various

Give approximate average number.

Average number of times per class: pause to ask for questions_____

Average number of times per class: have small group discussions or problem solving _____

Average number of times per class: show demonstrations of solving a problem, simulations, or video clips_____

Average number of times per class: show demonstrations of solving a problem, simulations, or video where students first record predictions (write down, etc.) and then afterwards explicitly compare observations with predictions_____

Average number of discussions per term on why material is useful and/or interesting from students' perspective _____

Comments on above (if any): _____

Check all that occurred in your course:

- ❑ Students asked to read/view material on upcoming class session
- ❑ Students read/view material on upcoming class session and complete assignments or quizzes on it shortly before class or at beginning of class
- ❑ Reflective activity at end of class, e.g. “one-minute paper” or similar (students briefly answering questions, reflecting on lecture and/or their learning, etc.)
- ❑ Student presentations (verbal or poster)

Fraction of typical class period you spend lecturing/ talking to whole class (presenting content, deriving mathematical results, presenting a problem solution, …)

- o 0-20%
- o 20-40%
- o 40-60%
- o 60-80%
- o 80-100%

Considering the time spent on the major topics, approximately what fraction was spent on the process by which the theory/model/concept was developed?

- o 0-10%

- 11-25%
- more than 25%

B. Individual Student Responses (ISR)

If a student response method is used to collect responses from all students IN REAL TIME IN CLASS, what method is used? (check all that occurred in your course)

- ❑ raising hands
- ❑ raising colored cards
- ❑ electronic ("clickers") with student identifier
- ❑ electronic anonymous
- ❑ written student responses that are collected and reviewed in real time
- ❑ Other (please specify) _____

Number of student response system questions posed followed by student-student discussion per class ___

Number of times student response system used as quiz device (counts for marks and no student discussion) per class ____

IV. Assignments (check all that occurred in your course)

- ❑ Homework/problem sets assigned or suggested but did not contribute to course grade
- ❑ Homework/problem sets assigned and contributed to course grade at intervals of 2 weeks or less
- ❑ Paper or project (an assignment taking longer than two weeks and involving some degree of student control in choice of topic or design)
- ❑ Encouragement and facilitation for students to work collaboratively on their assignments
- ❑ Explicit group assignments
- ❑ Other (please specify) _____

V. Feedback and testing; including grading policies (check all that occurred in your course)

A. Feedback from students to instructor during the term

- ❑ Midterm course evaluation
- ❑ Repeated online or paper feedback or via some other collection means such as clickers
- ❑ Other (please specify) _____

B. Feedback to students (check all that occurred in your course)

- ❑ Assignments with feedback from instructor, teaching assistant, or peer before grading or with opportunity to redo work to improve grade

- ❑ Students see graded assignments
- ❑ Students see assignment answer key and/or grading rubric
- ❑ Students see graded midterm exam(s)/ quizzes
- ❑ Students see midterm exam(s)/ quizzes answer key(s)
- ❑ Students explicitly encouraged to meet individually with you
- ❑ Other (please specify) _____

C. Testing and grading

Number of tests during term that reflect course expectations (e.g. midterm exams, but not final exams _____

Percent of exam questions that required students to explain reasoning _____

Approximate breakdown of course mark (% in each of the following categories)

Final Exam	_____%
Midterm Exam(s)	_____%
Homework assignments	_____%
Paper(s) or project(s)	_____%
In-class activities	_____%
In-class quizzes	_____%
Online quizzes	_____%
Participation	_____%
Lab component	_____%
Other	_____%

If you selected other, please specify: _____

VI. Other (check all that occurred in your course)

- ❑ Assessment given at beginning of course to assess background knowledge
- ❑ Use of instructor-independent pre-post test (e.g. concept inventory) to measure learning
- ❑ Use of a consistent measure of learning that is repeated in multiple offerings of the course to compare learning
- ❑ Use of pre-post survey of student interest and/or perceptions about the subject
- ❑ Opportunities for students' self-evaluation of learning
- ❑ Students provided with opportunities to have some control over their learning, such as choice of topics for course, paper, or project, choice of assessment methods, etc.
- ❑ New teaching methods or materials were tried along with measurements to determine their impact on student learning

VII. Training and guidance of Teaching Assistants (check all that occurred in your course)

- ❑ No TAs for course
- ❑ TAs must satisfy English language skills criteria
- ❑ TAs receive ½ day or more of training in teaching
- ❑ There are Instructor-TA meetings every two weeks or more frequently where student learning and difficulties, and the teaching of upcoming material are discussed.
- ❑ TAs are undergraduates
- ❑ TAs are graduate students
- ❑ Other (please specify) _____

VIII. Collaboration or sharing in teaching (select the response that best fits the materials that you use in your teaching)

- ❑ Used or adapted materials provided by colleague(s)
- ❑ Used "Departmental" course materials that all instructors of this course are expected to use
- ❑ Other (please specify) _____

Discussed how to teach the course with colleague(s)

- o 1 Never
- o 2
- o 3
- o 4
- o 5 Very Frequently

Read literature about teaching and learning relevant to this course

- o 1 Never
- o 2
- o 3
- o 4
- o 5 Very Frequently

Sat in on colleague's class (any class) to get/share ideas for teaching

- o 1 Never
- o 2
- o 3
- o 4
- o 5 Very Frequently

IX. General (open-ended comments)

Please write any other comments here. If this inventory has not captured an important aspect of your teaching of this course, or you feel you need to explain any of your above answers please describe it here.

_____

_____

_____

We thank you for your time spent taking this survey.

Note. Adapted from "The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science," by C. Wieman and S. Gilbert. *CBE- Life Sciences Education, 13(3),* p. 563. (http://www.cwsei.ubc.ca/Files/CWSEI_TeachingPracticesInventory_Oct2014.pdf) and from "CWSEI Teaching Practices Inventory," by Carl Wieman Science Education Initiative. Retrieved August 2, 2021, from https://cwsei.ubc.ca/sites/default/files/cwsei/resources/tools/CWSEI_TeachingPracticesInventory_Oct2018-TC.pdf

Appendix B

Teaching Dimensions Observation Protocol (TDOP): Coding Section

Minutes	0:00-4:59	5:00-9:59	10:00-14:59
Teaching Methods	LEC IL DEM SGW MM CS WP OT CD RQ DCQ DAQ CQ NQ DW	LEC IL DEM SGW MM CS WP OT CD RQ DCQ DAQ CQ NQ DW	LEC IL DEM SGW MM CS WP OT CD RQ DCQ DAQ CQ NQ DW
Notes: Include brief description of what the instructor is actually doing here (e.g. content is being discussed, etc.)			
Cognitive Engagement	RM PS CR IN CN	RM PS CR IN CN	RM PS CR IN CN
Notes:			
Instructional Technology	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T	PO BB LC CL B OP D OB P T

Note. This coding table shows a 15-minute total time frame for demonstration, additional pages were added to capture up to 16 intervals of 5 minute lengths. Adapted from "Instructional Systems of Practice: A Multidimensional Analysis of Math and Science Undergraduate Course

Planning and Classroom Teaching," by M. T. Hora and J. J. Ferrare, 2013, *Journal of the Learning Sciences, 22,* p. 257. (https://doi.org/10.1080/10508406.2012.729767)

References

Addy, T., Simmons, P., Gardner, G., & Albert, J. (2015). A new "class" of undergraduate professors: examining teaching beliefs and practices of science faculty with education specialties. *Journal of College Science Teaching,* 44(3), 91-99.

Allendoerfer, C., Wilson, D., Kim, M. J., & Burpee, E. (2014). Mapping beliefs about teaching to patterns of instruction within science, technology, engineering, and mathematics. *Teaching in Higher Education, 19(7),* 758-771, http://dx.doi.org/10.1080/13562517.2014.901962

Alsharif, K. M., & Alamri, N. M. (2020). Using Teaching Practices Inventory to Evaluate Mathematics Faculty Teaching Practices in Higher Education. *International Journal of Instruction, 13(1),* 139-150. https://doi.org/10.29333/iji.2020.1319a

Angelo, T., & Cross, K. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed). San Francisco, CA: Jossey-Bass.

Argyris, C. (1995). Action science and organizational learning. *Journal of Managerial Psychology, 10(6),* 20-26.

Bailey, T., Smith Jaggars, S., & Jenkins, D. (2015). *Redesigning America's community colleges.* Cambridge, MA: Harvard University Press.

Barnes, L., Bull, K., Campbell, N., & Perry, K. (1998). Discipline related differences in teaching and grading philosophies among undergraduate teaching faculty. *American Educational Research Association,* Annual Meeting Presentation, 1-23.

Bartell, T., Wager, A., Edwards, A., Battey, D., Foote, M., & Spencer, J. (2017). Toward a framework for research linking equitable teaching with the standards for mathematical practice. *Journal for Research in Mathematics Education, 48*(1), 7-21.

Beach, A., Henderson, C., & Finkelstein, N. (2012). Facilitating change in undergraduate STEM education. *Change: The Magazine of Higher Learning,* 44(6), 52-59.

Brown, P., Abell, S., Demir, A., & Schmidt, F. (2006). College science teachers' views of classroom inquiry. *Science Education,* 90, 784-802.

Carl Wieman Science Education Initiative. (2018, October). *CWSEI Teaching Practices Inventory.* Retrieved August 2, 2021, from https://cwsei.ubc.ca/sites/default/files/cwsei/resources/tools/CWSEI_TeachingPracticesInventory_Oct2018-TC.pdf

Corbin, J., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology,* 13(1), 3–21.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Dandy, K. L., & Bendersky, K. (2014). Student and faculty beliefs about learning in higher education: Implications for teaching. *International Journal of Teaching and Learning in Higher Education, 26(3),* 358-380.

Duckworth, A. (2016). *Grit.* Scribner.

Edwards, A. R., Sandoval, C., & McNamara, H. (2015). Designing for improvement in professional development for community college developmental mathematics faculty. *Journal of Teacher Education, 66(5),* 466-481.

Ellis, J. (2014). Preparing future professors: Highlighting the importance of graduate student professional development programs in calculus instruction. In S., Oesterle, P., Liljedahl, C., Nicol, & D., Allan (Eds.), *Proceedings of the Joint Meeting of PME 38 and PME-NA 36,* Vol. 3, (pp. 9-16). Vancouver, Canada: PME.

Ernest, P. (1994). *The impact of beliefs on the teaching of mathematics.* In A. Bloomfield & T. Harries (Eds.), *Teaching and Learning Mathematics,* Derby: Association of Teachers of Mathematics. (http://socialsciences.exeter.ac.uk/education/research/centres/stem/publications/pmej/impact.htm)

Gandhi-Lee, E., Skaza, H., Marti, E., Schrader, P., & Orgill, M. (2015). Faculty perceptions of the factors influencing success in STEM fields. *Journal of Research in STEM Education, 1*(1), 30-44.

Grant, T. J., Hiebert, J., & Wearne, D. (1998). Observing and teaching reform-minded lessons: What do teachers see? *Journal of Mathematics Teacher Education, 1,* 217–236.

Grubb, W. N. (1999). *Honored but invisible: An inside look at teaching in community colleges.* New York, NY: Routledge.

Grubb, W. N., & Gabriner, R. (2013). *Basic skills education in community colleges: Inside and outside of classrooms.* New York, NY: Routledge.

Holland, T. (2018). Impact of a departmental instructional skills course on graduate students' beliefs about science teaching and learning. *Journal of College Science Teaching,* 47(6), 57-65.

Hora, M. T. (2016). Navigating the problem of space of academic work: How workload and curricular affordances shape STEM faculty decisions about teaching and learning. *AERA Open, 2(1),* 1-19. doi: 10.1177/2332858415627612

Hora, M. T., & Anderson, C. (2012). Perceived norms for interactive teaching and their relationship to instructional decision-making: a mixed methods study. *Higher Education, 64,* 573-592.

Hora, M. T., & Ferrare, J. J. (2013). Instructional systems of practice: A multidimensional analysis of math and science undergraduate course planning and classroom teaching. *Journal of the Learning Sciences, 22,* 212-257. doi: 10.1080/10508406.2012.729767

Johnson, M. J., & Hall, J. L. (2007). Impact of one science teacher's beliefs on his instructional practice. *Journal of Education and Human Development,* 1.

Kane, R., Sandretto, S., & Heath, C., (2002). Telling half the story: a critical review of research on teaching beliefs and practices of university academics. *Review of Educational Research, 72(2),* 177-228.

Kember, D., (1997). A reconceptualization of the research into university academics' conceptions of teaching. *Learning and Instruction, 7(3),* 255-275.

Kember, D., & Gow, L. (1994). Orientations to teaching and their effect on the quality of student learning. *The Journal of Higher Education, 65(1),* 58-74. doi: 10.2307/2943877

Kensington-Miller, B., Sneddon, J., Yoon, C., & Stewart, S. (2013). Changing beliefs about teaching in large undergraduate mathematics classes. *Mathematics Teacher Education and Development,* 15(2), 1-16.

Koziol, S. M., Jr., & Burns, P., (1986). Teachers' accuracy in self-reporting about instructional practices using a focused self-report inventory. *Journal of Educational Research, 79(4), 205-209.*

Krathwohl, D. R. (2009). *Methods of education and social science research* (3rd ed.). Long Grove, IL: Waveland Press, Inc.

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Lam, T. C. M., & Bengo, P., (2003). A comparison of three retrospective self-reporting methods of measuring change in instructional practice. *American Journal of Evaluation, 24(1), 65-80.*

Laplante, B. (1997). Teachers' beliefs and instructional strategies in science: Pushing analysis further. *Science Education,* 81, 277-294.

Li, L. (2013). The complexity of language teachers' beliefs and practice: one EFL teacher's theories. *The Language Learning Journal, 41(2),* 175-191. doi: 10.1080/09571736.2013.790132

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry.* Newbury Park, CA: Sage.

Luft, J. A., & Roehrig, G. H., (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education,* 11(2), 38-63.

Martin, E., Prosser, M., Trigwell, K., Ramsden, P., & Benjamin, J., (2000). What university teachers teach and how they teach it. *Instructional Science, 28,* 387-412.

Mesa, V., Celis, S., & Lande, E. (2014). Teaching approaches of community college mathematics faculty: Do they relate to classroom practices? *American Educational Research Journal, 51(1),* 117-151. doi: 10.3102/00028311213505759

Mesa, V. & Griffiths, B. (2012). Textbook mediation of teaching: an example from tertiary mathematics instructors. *Education Studies in Mathematics,* 79(1), 85-107.

Moore, T., Guzey, S., Roehrig, G., Stohlmann, M., Park, M., Kim, Y. R., Callender, H., & Teo, H. J. (2015). Changes in faculty members' instructional beliefs while implementing model-eliciting activities. *Journal of Engineering Education,* 104(3), 279-302.

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all.* Reston, VA: NCTM.

National Research Council. (2000). *How People Learn: Brain, Mind, Experience, and School: Expanded Edition.* Washington, DC: The National Academies Press. https://doi.org/10.17226/9853.

National Research Council. (2013). *Educating engineers: Preparing 21st century leaders in the context of new modes of learning: Summary of a forum.* Washington, DC: The National Academies Press. http://www.nap.edu/openbook.php?record_id=18254

Nespor, J. K., (1985). *The role of beliefs in the practice of teaching: Final report of the teacher beliefs study.* National Institute of Education (ED). https://eric.ed.gov/contentdelivery/servlet/ERICServlet?accno=ED270446

Nespor, J. K., (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19(4),* 317-328. https://doi.org/10.1080/0022027870190403

Nghia, T. L. H., (2017). What hinders teachers from translating their beliefs into teaching behaviors: The case of teaching generic skills in Vietnamese universities. *Teaching and Teacher Education, 64,* 105-114. http://dx.doi.org/10.1016/j.tate.2017.02.003

Norton L., Richardson, J. T. E., Hartley, J., Newstead, S., & Mayes, J., (2005). Teachers' beliefs and intentions concerning teaching in higher education. *Higher Education, 50,* 537-571. doi: 10.1007/s10734-004-6363-z

Oleson, A., & Hora, M. T., (2013). Teaching the way they were taught? Revisiting the sources of teaching knowledge and the role of prior experience in shaping faculty teaching practices. *Higher Education, 68,* 29-45. doi: 10.1007/s10734-013-9578-9

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

Philipp, R. A. (2007). Mathematics teachers' beliefs and affect. In F. K. Lester, Jr. (Ed.), *Second Handbook of Research on Mathematics Teaching and Learning,* (pp. 257-315). Charlotte, NC: NCTM

President's Council of Advisors on Science and Technology. (2020) *Report to the President. Recommendations for strengthening American leadership in industries of the future.* Washington, DC: Executive Office of the President.

President's Council of Advisors on Science and Technology. (2012). *Report to the President. Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering and mathematics.* Washington, DC: Executive Office of the President.

Rabardel, P., & Waern, Y. (2003). From artefact to instrument. *Interacting with Computers, 15(5),* 641-645.

Reys, R., Cox, D., Dingman, S., & Newton, J. (2009). Transitioning to careers in higher education: Reflections from recent Ph.D.s in mathematics education. *Notices of the AMS, 56(9),* 1098-1103.

Rogers, E. (1995). *Diffusion of innovations.* The Free Press.

Ross, J. A., McDougall, D., & Hogaboam-Gray, A. (2003). A survey measuring elementary teachers' implementation of standards-based mathematics teaching. *Journal for Research in Mathematics Education, 34(4),* 344-363.

Rowland, T. (2009). Beliefs and actions in university mathematics teaching. In M. Tzekaki, M. Kaldrimidou, & H. Sakonidis (Eds.), *Proceedings of the 33rd Conference of the*

International Group for the Psychology of Mathematics Education, (Vol. 5, pp. 17-24). Thessaloniki: IGPME.

Rowland, T. & Turner, F. (2007). Developing and using the 'Knowledge Quartet': A framework for the observation of mathematics teaching. *The Mathematics Educator, 10(1),* 107-123.

Samuelowicz, K. & Bain, J. D., (2001). Revisiting academics beliefs about teaching and learning. *Higher Education, 41,* 299-325.

Shulman, L. (1986). Those who understand: Knowledge growth in teaching. *American Educational Research Association, 15(2)*, 4-14.

Speer, N. M., (2005). Issues of methods and theory in the study of mathematics teachers' professed and attributed beliefs. *Educational Studies in Mathematics, 58,* 361-391. doi: 10.1007/s10649-005-2745-0

Speer, N. M., (2008). Connecting beliefs and practices: A fine-grained analysis of a college mathematics teacher's collections of beliefs and their relationship to his instructional practices. *Cognition and Instruction, 26(2),* 218-267. doi: 10.1080/07370000801980944

Speer, N., & Hald, O. (2008). How do mathematicians learn to teach? Implications from research on teachers and teaching for graduate student professional development. In M. Carlson & C. Rassmussen (Eds.), *Making the connection: Research and teaching in undergraduate mathematics education,* (pp. 303-315). Washington, DC: The Mathematical Association of America.

Thompson, A. F. (1992). Teachers' beliefs and conceptions: A synthesis of research. In D. Grouws (Ed.), *Handbook of research in mathematics learning and teaching,* (pp. 127-146). New York: MacMillan.

Trigwell, K., Prosser, M., & Taylor, P. (1994). Qualitative differences in approaches to teaching first year university science. *Higher Education, 27(1),* 75-84, doi: 10.1007/BF01383761

Verillon, P., & Rabardel, P. (1995). Cognition and artifacts: A contribution to the study of thought in relation to instrumented activity. *European Journal of Psychology of Education,* 10, 77-101.

Weiman, C., (2015). A better way to evaluate undergraduate teaching. *Change, January/February,* 6-15.

Wieman, C., & Gilbert, S. L., (2014). The teaching practices inventory: A new tool for characterizing college and university teaching in mathematics and science. *CBE- Life Sciences Education, 13(3),* 552-569.

Williams, C. T., Walter, E. M., Henderson, C., & Beach, A. L., (2015). Describing undergraduate STEM teaching practices: A comparison on instructor self-report instruments. *International Journal of STEM Education, 2(18),* 1-14.

Yow, J. A., Eli, J. A., Beisiegel, M., McCloskey, A., & Welder, R. M. (2016). Challenging transitions and crossing borders: Preparing novice mathematics teacher educators to support novice K-12 mathematics teachers. *Mathematics Teacher Education and Development, 18.1,* 52-69.

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PRESENTATIONS

- "Web-Based Audience Response Systems for Student Engagement in the Math Classroom," 32nd International Conference on Technology in Collegiate Mathematics, Pearson, 2020 Virtual Conference

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