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Exploring Lesson Study as a Model of Professional Development for Higher Education Chemistry Instructional Teams

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by

Nicole Ashley Suarez

Committee in charge:

University of California San Diego

Professor Stanley M. Lo, Chair
Professor Stacey Brydges, Co-Chair
Professor Sherice Clarke

San Diego State University

Professor Melissa Soto
Professor Susan Nickerson

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University of California San Diego

San Diego State University

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Dedication

For my Parents and Brother – Thank you for lending me your shoulders to stand on. I am where I am because of your love and support.

For Grandma Zenaida and Auntie Nilda – Wish you were both here to witness me cross the stage one last time. I am forever grateful for your guidance and love.

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List of Abbreviations

5TP	Five Teaching Perspectives
CANMEE	California Action Network for Mathematics Excellence and Equity
CDOP	Classroom Discourse Observation Protocol
CHAT	Cultural-Historical Activity Theory
CIRTL	Center of the Integration of Research, Teaching, and Learning
CoP	Community of Practice
DBR	Design-Based Research
DBRC	Design-Based Research Collective
GTA	Graduate Teaching Assistant
K-12	Kindergarten through 12th grade
LS	Lesson Study
NASEM	National Academies of Science, Engineering, and Medicine
PD	Professional Development
PI	Principal Investigator
Prof.	Professor
RQ	Research Question
STEM	Science, Technology, Engineering, and Mathematics
TA	Teaching Assistant
VSEPR	Valence Shell Electron Pair Repulsion

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Vita

2016	Bachelor of Science, University of California San Diego
2018	Master of Science, University of California San Diego
2022	Doctor of Philosophy, University of California San Diego, San Diego State University

Abstract of the Dissertation

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Nicole Ashley Suarez

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Professor Stanley M. Lo, Chair
Professor Stacey Brydges, Co-Chair

Reform initiatives for improving undergraduate science, technology, engineering, and mathematics (STEM) education have identified graduate students as important stakeholders in these efforts. Graduate students often serve as graduate teaching assistants (GTAs) at some point in their graduate education and are positioned as future STEM faculty and mentors for the next generation of scientists. Therefore, institutions across the nation have recognized the importance of GTA professional development (PD) and have implemented some form of teaching PD for their graduate students. Yet, scholars suggest that current approaches to GTA PD are too focused on content and logistics and may not be providing graduate students with quality and effective PD (Schussler et al., 2015). Gardner and Jones (2011) suggest four necessary components of a

quality and effective GTA program: (a) intensive, ongoing, and connected to practice; (b) focused on student learning and addresses the teaching of specific curriculum content; (c) aligned with college or university improvement priorities and goals; and (d) building strong working relationships among colleagues. In this dissertation, I suggest Lesson Study (LS) as a quality and effective PD model for GTAs and higher education instructional teams.

The current study investigated the implementation of a modified LS model with two instructional teams, comprised of one course instructor, one lab coordinator and six GTAs, who taught virtual introductory chemistry labs during a summer academic term. The data I analyzed in this dissertation includes transcripts from weekly instructional team meetings, post-participation interviews with participating GTAs, and researcher-generated field notes.

I employed the Five Teaching Perspectives framework (Collins & Pratt, 2011) to characterize how LS mediates instructional team discourse around teaching. Findings suggest that LS promotes the apprenticeship and developmental perspectives. I also applied sociocultural theories of learning to understand how LS mediates the roles and responsibilities of GTAs within the larger departmental context. Findings suggest that LS gives instructional teams the opportunity to confront implicit departmental norms about teaching and establish new norms. Lastly, I used design-based research to produce four design features that enhance the LS process for GTAs and instructors in higher education.

Chapter 1: Introduction

The Boyer Commission Report (1998, 2001) made a noteworthy call to redesign graduate education in order to prepare their students for teaching undergraduates. More than a decade later, the American Association for the Advancement of Science (2011, 2015, 2018) continues to denote graduate students as important stakeholders in undergraduate science, technology, engineering, and mathematics (STEM) education and has called for institutions to consider and include graduate students in discussions and reform. This notion is further echoed by the Association of American Universities (2011) Framework for Systemic Change in Undergraduate STEM Teaching and Learning, where graduate students are recognized as crucial scaffolds necessary to support and sustain evidence-based teaching but require the professional development (PD) and resources to support their efforts.

While these reports emphasize the need for graduate student teaching PD in the context of improving undergraduate STEM education, the National Academies of Science, Engineering, and Medicine (NASEM, 2018) puts these calls into the perspective of the graduate student by highlighting how teaching is a valuable experience that all graduate students should have the opportunity to pursue. The NASEM (2018) report details studies that have documented how graduate students who have participated in teaching development programs and served as teaching assistants (TAs) are, in fact, better able to design compelling research studies and hypotheses compared to their counterparts who only serve as research assistants (Feldon et al., 2011; Trautmann & Krasny, 2006). Yet, despite the recognition of the importance of teaching experiences and teaching PD, there remains a lack of opportunities for graduate students across many disciplines to deepen their understanding and improve their teaching practice (Goodwin et al., 2018).

One of the major reasons why graduate students are vital to undergraduate STEM education is based on the fact that they often serve as graduate teaching assistants (GTAs). However, the GTA role is ill-defined. Winstone & Moore (2016) have previously described GTAs as being "neither fish nor fowl" because they are neither fully students nor fully teachers. Because of this positioning, GTAs often learn about the values and culture of teaching through their environment and through others. While PD can become a source for GTAs to learn this information, current literature indicates that comprehensive and meaningful teaching PD and support is lacking in many STEM graduate programs (Goodwin et al., 2018; Schussler et al., 2015), which ultimately communicates a devaluation of teaching (Nurrenbern et al., 1999; Sundberg et al., 2005). This project proposes the use of the Lesson Study model as PD for GTAs to advance and expand their understanding of teaching and the role they play in undergraduate STEM education.

Lesson Study Model

Originally a school-based PD model established in Japan, Lesson Study (LS), which is a translation of *jugyou kenkyuu*, is a form of action research that engages a group of instructors in a collaborative planning, teaching, and learning process (Isoda, 2007; Saito, 2012). More specifically, the LS model is cyclical and comprises of four phases: (a) study disciplinary curriculum and standards, (b) plan a lesson that anticipates student thinking and their learning trajectories, (c) teach the lesson and observe how students respond to planned prompts and activities, (d) reflect on student data to deepen understanding of instructional practice and student learning (Lewis et al., 2019). What sets LS apart from other PD opportunities is that the PD is locally situated and contextualized in the classroom; teachers are experts of their own classroom,

so forming a LS team builds a community of experts that work collaboratively to not only share knowledge but also develop shared knowledge (Collet, 2019; Lieberman & Wood, 2002).

At the turn of the century, LS gained traction in the United States of America (U.S.) and became the focus of many U.S. educational researchers (Stigler & Hiebert, 1999). Implemented in K-12 schools across the nation and around the world, researchers have reported a multitude of benefits for teachers who engage in LS, including: increased teacher pedagogical content knowledge (Coenders & Verhoef, 2019; Shúillebháin, 2015), increased teacher motivation (Lewis et al., 2012), enhanced teaching self-efficacy by emphasizing teacher agency (Collet, 2019), strengthened teaching collaboration by creating a professional community (Lieberman & Pointer Mace, 2010), and improved responsive teaching skills (Cajkler et al., 2015; Danielson, 2011; Schipper et al., 2017). While not as abundant, there is also research that reports on the implementation of LS in higher education settings, including with faculty (Bickerstaff et al., 2019; Cerbin & Kopp, 2006; Demir et al., 2013; Hervas, 2021; Soto et al., 2019) and with graduate students (Collet & Peñaflorida, 2020; Dotger, 2011; Lampley et al., 2018), but to my knowledge, there is only one report describing a LS team comprised of both mathematics faculty and graduate students who came together to focus on a one-hour lecture lesson for related rates (Alvine et al., 2007). The goal of my dissertation was to build on, expand, and contribute to existing research investigating LS in higher education. More specifically, I focused on implementing and characterizing the interactions of higher education instructional teams (i.e. course instructor, lab coordinator, and GTAs) participating in LS.

Study Context and Design

This study focuses on two instructional teams teaching two different virtual chemistry laboratory courses (Course 1 and Course 2), both of which are part of the introductory chemistry

series at a teaching-focused institution in California. The study occurred during the Summer 2021 academic term, in the midst of the COVID-19 pandemic, so the course as well as data collection took place virtually. The instructor of record was the same for both Course 1 and Course 2, as was the lab coordinator. The Course 1 instructional team consisted of the instructor of record, the lab coordinator, and two GTAs. The Course 2 instructional team consisted of the same instructor of record and lab coordinator, along with four GTAs. In sum, there were eight unique individuals that took part in this study. Both instructional teams engaged in a modified LS model where I served as both the facilitator and study researcher.

Positionality and Theoretical Framing

Recognizing the dearth of research on implementing LS with higher education instructional teams, I sought to investigate and characterize the ways in which the LS model mediates perspectives and culture around teaching. The design of and motivation for this study stems from my own experience of being a graduate student and teaching assistant in biology at a research-intensive university. As I continue to develop my own conception of teaching, I reflect back on these early experiences. I recall attending a mandatory, four-hour morning orientation geared for first-time teaching assistants. The content of that orientation was focused on logistical details, including my responsibilities (i.e., attending lectures, holding office hours), the amount of hours I was expected to commit, and where I was supposed to turn to in the event of an emergency or suspected violation of academic integrity. While first serving in my role, I remember valuing the transmission of information. I saw my role as explaining the content a second time for students who did not fully comprehend the lecture given by the course instructor. I recall how I prepared for section; I mapped out “lesson plans” of what to write on the chalkboard, which mainly consisted of re-drawn textbook diagrams and simplified definitions of

biology terminology. The existence (or non-existence) of students in the room made no difference to my approach to teaching. I also remember that not all the faculty I worked with held regular meetings. In some instances, the only interaction I had with the faculty member and my fellow TAs was during exams to ensure proper proctoring. Because of the lack of collaboration with faculty and peers, I assumed that teaching was an individual activity.

After entering the field of education research, I have come to realize that I am not alone in my experiences. Many institutions still rely on a one-time, mandatory orientation that must be taken prior to one's first time being a GTA (Connolly et al., 2016; Goodwin et al., 2018; Schussler et al., 2015), and the content covered mainly includes teaching policies, classroom management, and content (Abbott et al., 1989; Gardner & Jones, 2011; Schussler et al., 2015). It is often the case that these orientations are administered by campus centers for teaching and learning segregated from the disciplines of GTAs (Denecke et al., 2017; von Hoene, 2011). More extensive PD typically comes in the form of a separate class (Hammrich, 2001; McManus, 2002; Roehrig et al., 2003; Bond-Robinson & Rodrigues, 2006; Baumgartner, 2007), but it is rare for GTAs to have the opportunity to partake in PD that is targeted towards the course they are currently teaching (Gormally et al., 2011). However, even after participation in such PD opportunities, STEM GTAs continue to adhere to a transmission perspective of teaching, which demonstrates a prioritization and commitment to efficiently and accurately delivering content knowledge (Gardner & Jones, 2011; Goertzen et al., 2010).

Furthermore, the notion of the research-teaching tradeoff, which suggests that teaching is secondary to research, is often communicated to graduate students upon entering their programs (Beath et al., 2012; Brownell & Tanner, 2012). Such discourse often leaves graduate students

isolated and unsupported in what is often their first venture into an educational role (Connolly, 2010; Luft et al., 2004; Marquis et al., 2020).

For the reasons stated above, I was interested in understanding how LS could impact the ways higher education instructors talk about teaching. Therefore, in this dissertation, I leveraged sociocultural theories of learning to guide how I collected, analyzed, and presented my data. A sociocultural perspective asserts that an individual's environment (i.e. the cultural, institution, and historical contexts) affects the way that individual acts and behaves (Lantolf, 2000). I heavily draw on Engeström's (1999; 2001) Cultural-Historical Activity Theory (CHAT) which compartmentalizes the mediators of an individual's environment by the (a) tools or resources that an individual uses or engages in, (b) community members that are within the environment, (c) division of labor among community members, and (d) norms followed by the community. Using such a lens allowed me to consider how LS structure, activities, and prompts facilitate certain discussions, beliefs, dynamics, and interactions between LS team members and their environment.

Research Questions

To focus my investigation, I was guided by three research questions (RQs).

RQ1: What teaching perspectives are the instructional team operating from throughout the course of the LS?

RQ1 provides insight into the ways instructional team members talk about teaching throughout the LS. For this RQ, I leveraged the Five Teaching Perspectives (5TP) framework (Collins & Pratt, 2011), which suggests there are five different ways to think about, approach, and practice teaching (i.e. teaching as transmission, apprenticeship, developmental, nurturing, or social reform). These perspectives will be further expanded on in Chapter 2, but essentially there

are different values and priorities for each perspective. In my analysis of the discourse during LS team meetings, I use the 5TP framework to identify what teaching beliefs and values team members communicated to one another and in response to the different components and prompts from the LS model.

RQ2: What are the communities, division of labor, and norms that impact the ways the instructional teams engage in LS?

As a direct application of CHAT, RQ2 considers the different environments, or systems, that instructional team members are a part of. In my analysis, I identified two systems: (a) the LS system consisting of the LS team members, and (b) the broader departmental system. In my analysis of LS meeting discourse and individual interviews with GTAs, I determined the communities, division of labor, and norms for each system, and I investigated the ways in which the norms and dynamics of the broader departmental system influence the norms and dynamics of the LS system.

RQ3: What design features support the implementation of LS with higher education instructional teams?

Recognizing the limited number of reports on implementing LS with higher education instructional teams, I wanted to contribute insights applicable for practice. From my analysis of my own field notes as LS facilitator and researcher, and with support from existing literature and study data, I present four design features that future LS facilitators should consider when trying to implement LS with higher education instructional teams.

Organization of Dissertation

In Chapter 2, I provide an overview of existing research related to the two main domains of my study: (a) models and approaches to GTA PD, and (b) the LS model and resulting insights,

benefits, and challenges. Also in Chapter 2, I expand on the tenets and assumptions of sociocultural theories of learning.

In Chapter 3, I describe Design-Based Research, which is the methodological framework I employed. Additionally, I further contextualize the study setting and describe the timeline and logistics of the modified LS model that I implemented with the instructional teams. Finally, I outline the data collection and analysis procedures that I used for this study.

In Chapter 4, I present the data and analysis for RQ1, which characterizes the teaching perspectives of instructional team members over the course of LS. I employ a case study approach to highlight how LS structures and prompts may be mediating such perspectives.

In Chapter 5, I present the data and analysis for RQ2, which investigates the communities, division of labor, and norms of the LS and departmental systems and examines how the systems interact with one another.

In Chapter 6, I present the data and analysis for RQ3, which highlights design features that enhance the implementation of LS with higher education instructional teams.

In Chapter 7, I situate my study findings into the broader LS and GTA PD literature and evaluate if the LS implemented in this study could be considered successful. I also reflect on and glean insights from my experiences serving as LS facilitator.

In Chapter 8, I conclude my dissertation by summarizing my findings, acknowledging the limitations of my study, and suggesting avenues for future research.

Chapter 2: Literature Review

I organize this chapter into four main sections. In the first section, I review the foundational and current literature on GTA PD and highlight existing models, approaches, and challenges encountered. In the second section, I expand on my description of the LS model to detail the goals and activities of each LS phase, then describe previous investigations on how the LS model has been implemented in K-12 and higher education settings. In the third section, I elaborate on sociocultural theories of learning and present the assumptions that guide my inquiry and the study design. Finally, I provide motivation for each of the research questions using theoretical and empirical literature presented in the chapter.

GTA Professional Development

GTAs are vital to undergraduate STEM instruction, especially at large research universities. The GTA position has its own niche within higher education in North America (Park, 2004; Winstone & Moore, 2016). That is, GTAs serve a number of needs and hold responsibilities which include lecturing, conducting review sessions, advising students, overseeing instructional laboratories, and designing and grading assignments and exams (Jacobs, 2002). Carrying these responsibilities place GTAs in crucial positions that define the quality of undergraduate STEM education (Commander et al., 2000; Muzaka, 2009; O'Neal et al., 2007), yet they are constantly overlooked during undergraduate instruction reform efforts. The work from this dissertation seeks to meaningfully contribute to the growing empirical work on GTA PD, which is currently not well understood or supported.

Models of GTA Development

Graduate students hold multiple roles during their time in their degree programs. These roles include being a student, a researcher, and a teacher (van Valkenburg & Arnett, 2000).

Graduate education is often conceptualized as a process of socialization with stages in which students acquire, commit, and form identities around the aforementioned roles (Austin & McDaniels, 2006; Weidman et al., 2001). What is particularly relevant to the research foci of this dissertation is how GTAs develop as teachers, which I define here as *GTA development*. Below, I describe two models of GTA development: (a) the teaching apprenticeship model, and (b) the Learner to Colleague model, which serves as an application of the teaching apprenticeship model.

Teaching Apprenticeship Model

The most commonly used model for GTA PD is the teaching apprenticeship model (Walker et al., 2008). In a teaching apprenticeship model, GTAs learn about their role and responsibilities from the faculty who serves as the instructor of record for the course. However, studies in the literature have highlighted several issues regarding its implementation. Firstly, seeing the GTA role as an apprenticeship to a faculty position communicates the idea that teaching is an ability that comes when enough experience is accumulated (Korpan, 2014; Luft et al., 2004). This conveys an assumption that teaching is a secondary outcome of graduate socialization and suggests that formalized training is not necessary (Shannon et al., 1998). Additionally, this communicated notion that training in teaching is simply not necessary makes it so graduate students find it difficult to justify their desire to refine their teaching skills (Nurrenbern et al., 1999; Sundberg et al., 2005), contributing to the perceived tension between research and teaching in the sciences (Connolly et al., 2016). This phenomenon, commonly referred to as the research-teaching tradeoff, is characterized by the belief that time and effort spent on teaching deters the research productivity of graduate students (Austin, 2002; Torvi, 1994). However, existing evidence supports that graduate student teaching responsibilities do not

have a negative impact on their degree completion (Connolly et al., 2016) or research publications (Shortlidge & Eddy, 2018). In fact, as mentioned in the introduction, graduate students who serve as teaching assistants also enhance their research skills (Feldon et al., 2011; Trautmann & Krasny, 2006). Nonetheless, this research-teaching tradeoff is often reinforced by institutional and departmental structures as well as faculty research advisors, most likely because research is perceived as a more rigorous activity and brings in financial compensation, publications, and prestige to the institution, department, and research labs (Beath et al., 2012; Brownell & Tanner, 2012; Shortlidge & Eddy, 2018; Zotos et al., 2020).

The second issue with the teaching apprenticeship model is that faculty are often positioned as GTAs' main and only source of teaching information. While faculty have experiential knowledge about teaching content within their discipline that they can share with their GTAs, faculty are not often trained in evidence-based teaching strategies and may not be equipped with the pedagogical content knowledge needed to effectively teach the content. Additionally, issues arise when considering the power dynamics between faculty and GTAs. GTAs report hesitancy with talking to faculty about teaching (Austin, 2002). GTAs often opt out of initiating conversations with faculty about teaching because of fear that they will be perceived as incompetent; this is in part because of the reinforced notion of the research-teaching tradeoff and the idea that teaching is a secondary outcome of graduate student socialization (Seymour, 2005). Ambiguity about the roles of the apprenticeship model is also reason for GTAs' hesitancy around talking about teaching with faculty. Faculty are not typically given explicit obligations or tasks to support their GTAs, and GTAs are often unsure of what type of support faculty can provide for them (Korpan, 2014). Additionally, teaching apprenticeships assume a mimicry mechanism and completely disregard the GTA as an individual with existing and developing

knowledge, beliefs, and skills about teaching (Allen & Rueter, 1990; Korpan, 2014; Long et al., 1996); incongruence between how faculty and graduate students think about and perceive the GTA role can be a source of tension (Lee et al., 2017). Reports have indicated that faculty often view GTAs as faculty support rather than as student support, leading to conversations centered around job responsibilities rather than pedagogical knowledge and teaching skills, stunting GTAs' professional growth (Hoessler & Godden, 2015; Lee et al, 2017; Nasser-Abu Alhija & Fresko, 2020).

Learner to Colleague Model

Nyquist and Sprague (1998) provide a three-stage model of GTA development, which proposes that GTAs move through three general roles: (a) senior learner, (b) colleague-in-training, and (c) junior colleague, and changes in development can occur in four different dimensions: (a) their concerns, (b) their discourse level, (c) their approach to authority, and (d) their approach to students. For the purposes of this dissertation, I refer to this model as the *Learner to Colleague* model.

In the *senior learner stage*, GTAs closely identify with their undergraduate students. GTAs are greatly concerned with how students perceive them and often give simplistic explanations to describe content within their discipline. In this stage, GTAs are heavily dependent on their faculty supervisor and strive to be liked by their students, which often result in the personalizing of interactions with faculty advisors and students; thus, GTAs' teaching beliefs and practices are guided by their emotions.

In the *colleague-in-training* stage, GTAs are concerned with refining their pedagogical skills. Their discourse with students often includes technical language of the discipline. GTAs become independent from, or perhaps even express disagreements with, faculty supervisors. This

parallels the relationships GTAs have with their students as GTAs detach themselves from students and focus on controlling the curriculum and pedagogy of the course.

In the final stage of this model, GTAs reach *junior colleague* status where they become concerned with student learning and strive to clearly and effectively communicate disciplinary content. Possessing such goals position GTAs as colleagues of their faculty supervisors; there is mutual trust and autonomy given to GTAs by their faculty supervisors because of the shared responsibility both have to the students. GTAs reconnect with their students but do not feel as vulnerable as the senior learner stage, demonstrating professional maturity and centering the interpersonal relationships (Nyquist & Sprague, 1998).

Characterizing GTA Teaching Professional Development

Teaching Apprenticeship and Learner to Colleague serve as enculturation models that lay out a trajectory of how GTAs evolve into teachers. Considering the implications for such models, institutions have responded to national calls for GTA development and recognized the importance of having more formalized teaching PD opportunities for graduate students (Schussler et al., 2015; Sundberg et al., 2005). In a survey administered to 71 institutions across the U.S., 96% of those institutions required some form of teaching PD for their graduate students (Schussler et al., 2015). However, the approaches to GTA PD are not uniform and there are a multitude of different structures that institutions implement (Gardner & Jones, 2011; Luft et al., 2004; Pentecost et al., 2012).

Belnap & Allred (2009) surveyed institutions across the U.S. about their GTA preparation programs and identified four different categories that are characterized by the duration of the PD: (a) orientation programs that occur only at the beginning of a GTA's teaching experience; (b) transitional programs that take place partly before and partly during a

course assignment; (c) refresher programs that are offered repeatedly at the beginning of each term; and (d) establishment programs that last throughout a term. Institutions can implement one of these four structures or a combination of multiple (Belnap & Allred, 2009).

STEM departments often opt for an orientation program structure in which new GTAs learn the rules and responsibilities associated with their roles (Hardré & Burris, 2012; Jones, 1993; Luft et al., 2004; Ridgway et al., 2017). However, these one-time orientations rarely extend beyond classroom management and logistics (Gardner & Jones, 2011; Schussler et al., 2015). Others in the literature have reported the implementation of establishment programs, which offer GTAs more extensive PD seminar courses with regularly scheduled meetings and activities (Schussler et al., 2008; Wyse et al., 2014). Yet, the topics covered in such programs remain similar to an orientation program and provide extended discussion on teaching policies, classroom management, course content, and teaching technique (Schussler et al., 2015). Some PD programs do integrate learning theories and lesson planning, but the frequency of these topics were to a much lesser extent, and GTAs report wanting a heavier emphasis on these aspects of teaching.

Gardner and Jones (2011) suggest four necessary components for a quality and effective GTA PD program. PD should be: (a) intensive, ongoing, and connected to practice; (b) focused on student learning and addressing the teaching of specific curriculum content; (c) align with college or university improvement priorities and goals; and (d) aimed at building strong working relationships among colleagues. Wyse et al. (2014) added an additional dimension by recognizing a need to contextualize PD to the classes GTAs were currently teaching. While over a decade has elapsed since the identification of these necessary GTA PD components, more

recent literature still echoes these sentiments (Ridgway et al., 2017), demonstrating a serious need to reconsider structures and approaches to GTA PD.

It is imperative that both researchers and practitioners consider why there is such a need for quality PD. Tanner and Allen (2006) reported that faculty in STEM disciplines heavily rely on the training they received as GTAs to inform their pedagogical practices as postsecondary instructors, suggesting that in order to shift the teaching attitudes and practices of faculty, researchers should pay special consideration to developing PD programs for GTAs as they are the future faculty. Improvement and investment in GTA PD will also benefit the graduate students who do not pursue academic teaching; in addition to enhancing research skills (Feldon et al., 2011; Gilmore et al., 2014; Trautmann & Krasny, 2006), teaching PD and experience can increase proficiency in science communication and mentoring ability, two areas where graduate students are reported to lack (Kuehne et al., 2014; Pfund et al., 2006; Sevian & Gonsalves, 2008).

Faculty Involvement in GTA PD

There is a limited number of studies documenting PD programs that facilitate collaborative opportunities between GTAs and faculty instructors (Schussler et al., 2015). One of the seminal works that shed light on such an opportunity is Seymour's (2005) book which describes the outcomes of three STEM classroom innovations that engaged TAs in collaborations that extended beyond the traditional TA role. Three types of new TA roles emerged from these studies: (a) creative troubleshooters, (b) consultants, and (c) collegial collaborators. *Creative troubleshooters* were TAs who used their own knowledge and skills to address daily issues but would notify faculty of issues when they deemed it beyond their capabilities. *Consultants* were TAs who provided feedback and advice to faculty based on their own experiences. Lastly,

collegial collaborators were TAs who gained a sense of ownership over their teaching and "shouldered responsibility for student learning alongside faculty" (p. 137) by creatively facilitating student learning. This type of partnership was termed collaborative engagement.

Seymour's (2005) description of collaborative engagement work opened up new possibilities for how the GTA role could be reimagined. Yet, it left me pondering how to foster GTA ownership. Especially within STEM courses, GTAs do not often have the autonomy to refine course curriculum because it is constructed by the faculty or by the department (Seymour, 2005), but having no sense of autonomy is one reason why GTAs may feel hesitant or uncertain when teaching (Kendall & Schussler, 2012; Muzaka, 2009). The collaborative nature of LS, as will be detailed later in this chapter, is one reason why I believe this model would be an effective PD opportunity; I hypothesized that the LS model would facilitate collaboration among course instructor and GTAs and create a sense of shared ownership.

Peer Involvement in GTA PD

The literature has emphasized the importance of peers in GTA PD. GTAs often pursue teaching support through their peers (Myers, 1994; Staton & Darling, 1989). Mena et al. (2013) discussed how GTAs often confide in their peers about issues they encounter in their teaching because peers provide a sense of shared experiences. Marquis and colleagues (2020) noted that GTAs commonly provide and receive advice from one another, most especially on grading rubrics. However, these peer exchanges are often reported to occur in informal structures (i.e. conversations with friends or lab mates) (Corcoran & Clark, 1984; Wulff et al., 2004), which may perhaps be an artifact of the absence of peers in GTA development models. While there have been reports of PD programs that facilitate the exchange of peer feedback on exam items or assignments (Reeves et al., 2016; Wyse et al., 2014), there is a need to further explore PD

structures that promote peer interactions around teaching. I hypothesized that the LS model would also encourage collaboration among GTAs and their peers.

The Lesson Study Model

As described in Chapter 1, LS is a PD model that was created in Japan and it continues to remain a widely used practice in schools; approximately 90% of schools in Japan practice LS (Chichibu & Kihara, 2013). LS teams appear at many different career and organizational levels. For example, individual schools conduct LS with teachers organized based on grade level (Yoshida, 2000). Pre-service and first-year teachers often participate in LS with experienced teachers as a method of socialization into their new careers (Fernandez et al., 2003). Groups of established teachers often form regional or cross-district LS teams based on subject matter or career stage (Murata & Takahashi, 2002). Even research organizations form LS teams at the national level to explore and investigate new teaching practices and curriculum (Murata & Takahashi, 2002).

While it is heavily implemented model in Japan, LS has only recently gained traction in the United States. Stigler and Hiebert (1999) presented their ethnographic accounts of LS in the Third International Mathematics and Science Study, which was sponsored by the International Association for the Evaluation of Educational Achievement to measure international trends in math and science achievement. Since Stigler and Hiebert's (1999) documentation of LS, many U.S. educational researchers, especially those investigating math education, have focused on modifying the model to fit the needs of U.S. schools and studying its impact on students and teachers (Stepanek et al., 2007).

Phases of LS

Although different researchers have embraced a variety of names for the phases of the LS cycle, and, in some cases, have extended the number of phases, there are traditionally four major steps in one PD cycle: (a) study, (b) plan, (c) teach, and (d) reflect (Lewis et al., 2019). In the *study phase,* the LS team studies the current curriculum and discipline-specific standards in order to identify a unit or topic that they would like to investigate. Once a topic is chosen, the team will also study common student misconceptions regarding the topic and review the ways this lesson has been taught before. In the *plan phase*, the team selects and revises a lesson based on the information and evidence gathered in the study phase. In the *teach phase*, one team member teaches the lesson to students while the other members observe and collect student data. In the final stage of the cycle, *the reflect phase*, the team reflects on and discusses their experiences, observations, and collected student data to deepen their understanding of how students learn.

In addition to a group of teachers, the LS team may include a facilitator who assumes logistical responsibilities and provide scaffolds and guidance to teams who may be new to the LS process. Facilitators are often researchers or practitioners who have studied and experienced the LS process before. However, it is common that as the group gains experience with LS and becomes self-sustaining, the facilitator is no longer needed and completely removed from the team.

At the superficial level, it seems that characteristics of each of these four phases are encompassed within existing PD approaches already in use in the U.S. For example, collection and analysis of student work in the third and fourth phases of LS is common practice in pre-service teacher preparation, and reviews of videotaped instruction is a known source for instructional improvement (Santagata & Angelici, 2010; Windschitl et al., 2012). However,

Lewis and colleagues (2002a, 2004) argue that though there is some overlap, there is no existing PD approach that completely matches the elements of LS, including the central focus around a classroom lesson. The opportunity to contextualize teaching and learning in a classroom allows instructors to not only theoretically hypothesize the relationship between teaching and learning, but also test and experience it as well.

LS in K-12 Setting

The majority of research on LS in the U.S. is contextualized within the K-12 educational setting. In a review of the LS literature conducted by Cheung and Wong (2014), empirical work suggests a multitude of positive impacts on both teacher learning and student learning. In order to summarize and organize the extensive literature of LS research, I categorize findings based on Lewis et al.'s (2009) framework which suggests LS promotes change in three different areas: (a) teachers' knowledge and beliefs, (b) professional community, and (c) teaching-learning resources.

Changes in Teacher Knowledge and Beliefs

Engagement in LS has been attributed to increased teacher professional knowledge and skill, as well as development of strong pedagogical content knowledge (Akerson et al., 2017; Coenders & Verhoef, 2019; Leavy & Hourigan, 2016; Lucenario et al., 2016; Shúilleabháin, 2015). While all phases contribute to teacher learning, scholars have specifically attributed gains in teacher professional knowledge and skill in the plan phase because this is typically where LS team members share their own knowledge and experiences, creating a collective knowledge that is considered and leveraged to plan the lesson (Coenders & Verhoef, 2019; Shúilleabháin, 2015). Cajkler et al. (2015) and Schipper et al. (2017) report that participation in LS gives teachers the opportunity to develop a greater awareness of students' needs in the classroom and a deeper

understanding of how teachers can respond to these needs. Widjaja et al. (2017) proposes that the enactment and reflection process built into the LS model mediates professional growth and gives teachers the space to integrate what they are experiencing into their beliefs about teaching.

Changes in Professional Community

As LS provides a formal venue for teachers to share their ideas about and experiences with teaching and learning, a sense of community is organically created (Cajkler et al., 2015; Huang & Shimizu, 2016; Lewis et al., 2006; Lieberman, 2009). The formation of a community is particularly important because teaching is often considered an isolated, individual activity, especially in the U.S. (Darling-Hammond & McLaughlin, 2011). In LS, teachers are essentially partaking in an investigative activity where they are trying to solve a problem they have encountered in their classrooms (Dudley, 2014). This shared goal encourages teachers to pool their knowledge and develop new suggestions for teaching and learning (Lofthouse & Thomas, 2017). This promotes the building of communal teacher professional knowledge rather than a focus on critiquing individual performance (Cajkler et al., 2015). The findings presented here suggest that the LS model can facilitate collaboration between GTAs, their peers, and faculty in ways that minimize feelings of incompetence and intimidation.

Changes in Teaching-Learning Resources

The LS model places great importance on instructional materials. Watanabe et al. (2008) highlight how existing curricula and lesson plans are necessary foundational pieces that help to identify issues with current teaching approaches and address how the lesson needs to be changed. Additionally, Lewis et al. (2009) proposes that LS elevates the ways teachers can use student work. Traditionally, student work is collected in order to be graded and evaluated for correctness. However, LS promotes the idea that student work is an opportunity for teachers to

gain insight into the minds of their students and reveal how they are thinking about the topic, which can be used to improve their own teaching practice and future lesson planning.

LS in Higher Education

Above, I briefly summarized the abundance of literature describing LS implemented in K-12 education. While this dissertation focuses on higher education instructors, the insights gained from the K-12 setting are still important to consider. However, I now turn to the less-investigated, yet steadily growing, literature on LS in higher education. I organize this section by first discussing empirical research related to LS with faculty, and then I discuss the empirical research related to LS with GTAs.

LS with Faculty

Cerbin and Kopp (2006) were the first to propose LS as a model for faculty PD. The faculty who participated in their study were drawn to the idea that LS focuses on *how* students learn rather than on what content they learn. Cerbin and Kopp (2006) specifically highlight how the plan phase facilitated opportunities for faculty to engage with student thinking, which was groundbreaking as student thinking had never been a focal point for faculty PD until then.

Through the investigation and analysis of a case study following six math and science faculty over a two-year period, Demir et al. (2013) were able to articulate the benefits and challenges of implementing LS with faculty. Participating faculty reported that participating in LS promoted (a) reform-based pedagogical practices, (b) reflective teaching practices, (c) awareness of student thinking and misconceptions, and (d) collaboration with colleagues. All of which are benefits that have been previously reported by K-12 teachers participating in LS.

In their same report, Demir et al. (2012) also highlighted five challenges that they encountered when implementing LS with faculty. The first challenge was that some faculty had

deeply ingrained and tenacious preexisting beliefs about teaching and learning that created tension between team members who held other beliefs. The second challenge was the often assumed equation of knowledge of content with knowledge of pedagogy, which hindered how faculty engaged with student thinking. The third challenge was the credibility of the LS facilitator. In the case of this study, the facilitator, who was a mathematics educator and not a mathematician, lacked credibility with some of the participants which impacted the team dynamic. The fourth challenge was the pervasive norm of teaching as an individual context. There were feelings of discomfort from faculty because they did not want to share the authority of planning a lesson, as well as feelings of hesitancy because they did not want others to observe their teaching. The final challenge was the difficulty in finding a time to meet, plan, and implement the revised lesson because of the numerous responsibilities that faculty carry. The challenge of time was also noted by Bickerstaff et al. (2019) who just started a LS project with mathematics instructors at a community college.

LS with GTAs

My review of the literature has pointed me to four reports on LS with GTAs. Due to the goal of this dissertation, in addition to reporting the findings of each study, I will also detail the context and structure of the implemented LS.

Dotger (2011) explored the impact of participation in one LS cycle with four GTAs for an undergraduate introductory lab course in earth science. The LS was structured into six, three-hour long seminars following the four traditional phases of LS, where the GTAs worked to redesign a lab. The LS team did not create a formal lesson plan, but they did formulate planning maps, worksheets, and quiz questions for students. Each GTA implemented the redesigned lesson in their lab section. While the researcher observed each of the GTAs' lesson, observations

by other LS team members were not required. The study focused on documenting the development of the GTAs' understandings of teaching and learning. Dotger (2011) noted that the discussions GTAs engaged in with each other during LS meetings provided evidence of small changes in their understanding of teaching and learning. Two of the four GTAs discussed the importance of students' prior knowledge when considering the impact of certain teaching strategies on student learning. Dotger (2011) also highlighted three study limitations for future researchers to consider. The first limitation is that the GTAs did not develop a shared lesson plan, which made it difficult for the GTAs to focus on student learning during the reflection phase. The second study limitation was that the GTAs lacked the knowledge of student-centered pedagogical approaches which resulted in the revised lesson maintaining didactic elements. The final limitation was that the GTAs in the study had no prior experience with articulating instructional goals, anticipating student thinking, and observing lessons—all which are crucial elements of the LS model. Dotger (2011) hypothesized that this lack of experience limited the GTAs' ability to think innovatively during the plan and reflect phases, emphasizing the need for a LS facilitator who could provide proper scaffolds that promote such thinking. Despite these limitations, the biggest benefit reported by participating GTAs was that LS served as a forum for them to grapple with their ideas on teaching and learning. Finally, Dotger (2011) highlighted the need for future LS implementations to consider how the involvement of faculty may encourage or inhibit GTA development during LS.

Lampley et al. (2018) implemented LS with four GTAs teaching lab sections for a general biology course and explicitly analyzed their data to measure changes in GTAs' pedagogical content knowledge. The structure and model of the LS took into consideration some of the study limitations mentioned by Dotger (2011). In the LS team, one of the participating

GTAs was pursuing a Ph.D. in Biology Education (as opposed to the others who were pursuing Biology), and was therefore designated as the LS facilitator who would mentor the team on pedagogical approaches. The LS team engaged in two lesson study cycles over a 16-week semester, and the topics for the lessons were determined by the researcher. Of the 16 weeks, weeks one through four were dedicated to revising the first lesson, while week five was scheduled for the teaching and reflection of the first lesson. The second cycle of LS occurred during weeks six through eleven with a new topic. One GTA was assigned to teach the first revised lesson, while another GTA taught the second revised lesson. The other GTAs served as observers to each of the lessons. The findings revealed that GTAs demonstrated growth in: (a) understanding the goals of science teaching, and (b) understanding the knowledge of instructional strategies. However, Lampley et al. (2008) also reported an observed disconnect between GTAs' beliefs about teaching and what was ultimately implemented by the GTAs in the lesson. For example, while one GTA repeatedly stated the phrase "teaching is not telling" throughout the LS cycles, the revised lesson still maintained a didactic format.

Collet and Peñaflorida (2020) explored the ways in which LS could support international GTAs. Using a case study approach, the study followed two international GTAs and one domestic GTA who were teaching an Introduction to Education course. The domestic GTA served as the LS team's facilitator because of their extensive prior teaching experiences in the K-12 setting. During a 16-week semester, the team engaged in a LS cycle that included teach, revise, re-teach, and reflect phases. The focal lesson was collectively agreed upon by all team members. In the first teach phase, the domestic GTA taught the lesson; then, the lesson was debriefed, revised, and co-taught the following day by the two international GTAs. The international GTAs self-reported an improvement in their instruction as a result of their LS

participation, which could be attributed to the opportunity to work with a more-experienced other. More specifically, the beliefs about teaching that were tied to the international GTAs' educational experiences in their home countries were challenged in the LS, but the discussions they had as a team and the opportunities they had to analyze and reflect on student learning encouraged them to reconsider their beliefs and change their practices to resolve the cognitive dissonances they felt that arose due to differences in cultural expectations. Collet and Peñaflorida (2020) suggest that because the international GTAs were able to question and restructure their beliefs and practices, their participation in LS supported transformative learning.

The final study in this section describes the implementation of LS with an instructional team of GTAs and an experienced faculty member. Alvine et al. (2007) detail their experience of working in a LS team comprised of an experienced teaching faculty member and GTAs teaching a mathematics course. While not specific, the LS team reported meeting for an hour each week over several months to engage in the LS process. For the first several meetings, the LS team members researched the LS model and the benefits of participating. The focal lesson was one class period in which the faculty member first introduced and solved an example problem in class and then students worked on worksheets in groups. The faculty member walked around to the groups offering help while the GTAs positioned themselves in different areas of the room observing the student groups. The team debriefed after the lesson and invited their students to share feedback on the lesson and work through problems so that the team could gain a better understanding of student thinking about the topic. The team reported that LS is an effective tool for improving pedagogy because it (a) provided space for GTAs to discuss pedagogy with an experienced other, (b) enabled GTAs to gain experience with implementing new pedagogical techniques, and (c) created a culture that valued teaching.

Theoretical Perspectives

While the above section represents the empirical literature that underpins the motivation of my research questions, in this next section, I will describe the theoretical perspectives that guided my inquiry, study design, and data analysis. As I mentioned in Chapter 1, I assume the tenets and principles of sociocultural theories of learning in this dissertation; this suggests that learners are not a self-regulating system as modeled by cognitive theories (Bruer, 2001; Gagné, 1970; Thorndike, 1922; von Glasersfeld, 1995), rather a learner is conceptualized into an individual that has an identity formed from social and cultural relations (Confrey 1995). In other words, the beliefs and practices that an individual holds and uses are products of cultural-historical processes (Pugh, 2017; Walshaw, 2016). In this study, I draw specifically on the features and constructs from three sociocultural theories of learning: (a) Vygotsky's Cultural-Historical Theory, (b) Cultural-Historical Activity Theory, and (c) Communities of Practice. The following subsections describe each of these three theories and their associated tenets.

Vygotsky's Cultural-Historical Theory

Russian psychologist, Lev Vygotsky, is often considered the pioneer that paved the way for sociocultural theories of learning. Vygotsky emphasized the influence of cultural factors on the cognitive development of a learner (Confrey, 1995; John-Steiner & Mahn, 1996). Included in these cultural factors are tools that have been developed based on the needs of the community. Tools convey a community's values, principles, and practices over time, and any activity that uses a tool is considered a mediated activity (Walshaw, 2016). *Mediation* is the process in which an individual uses a tool in order to control their thoughts, actions, behavior, and the world around them (Berger, 2005; Engeström, 1999). Vygotsky believed that both physical and psychological tools mediate human mental processes, such as thought regulation and problem

solving (Pugh, 2017). In other words, mediation is the mechanism that links an individual's internal process and the external world. Yet, it is important to note that the tools that an individual possesses, has access to, and uses impacts their quality of mental processes and their approaches to solving problems (Confrey, 1995; Pugh, 2017).

Language is a specific psychological tool that Vygotsky articulated as a representation of thoughts. Rather than viewing language as a means of expressing thought, Vygotsky believed that a thought only exists when put into words. The definition of *words*, here, is not strictly defined as spoken or written language. Instead, it is characterized as any means of communication, and the way a learner learns to communicate becomes the basis of their thinking and how they perceive the world (Schutz, 2004; Vygotsky, 1986). The idea of interdependence of thought and language has highlighted the importance of discourse in learning and development.

Cultural-Historical Activity Theory

The development of Cultural-Historical Activity Theory (CHAT) was spearheaded by Vygotsky's disciples, Alexei Leont'ev and Alexander Luria (Engeström, 1999; Lantolf, 2000). CHAT considers a broader outlook on Vygotsky's initial cultural-historical theory. That is, while Vygotsky acknowledged a connection between the internal mental processes of an individual and the external world, CHAT is a framework that can be used to understand *how* the external world gives rise to the human processes (Lantolf, 2000). Rather than viewing an individual's environment as one, all-encompassing construct, the CHAT framework breaks down an individual's environment into the tools used, the community, the norms within the community, and the division of labor among community members, creating a system. The different facets of this framework posit the existence of societal and collaborative impact on an individual's actions

(Engeström, 1999). When considering the community and its associated tools, norms, and division of labor, it is important to consider how the quality of and access to resources impacts the experience of individuals. Essentially, the resources that an individual has to work with can either enable or constrain the activity and interactions within the system (Gamoran, 2003).

Communities of Practice

Communities of Practice (CoP) is the final sociocultural theory of learning I discuss here. In Vygotsky's cultural-historical theory and CHAT, there was no explicit mention of what learning is and how it occurs. The CoP framework fills in this gap and suggests that learning is an enculturation of an individual into a community of practice (Lave & Wenger, 1991; Sfard, 1998). A community is defined as a group of people connected by a shared interest and seek to continuously learn to better their practices (Li et al., 2009; Riel & Polin, 2004). Wenger (1998) describes a CoP by discussing three interrelated dimensions: mutual engagement, joint enterprise, and shared repertoire. *Mutual engagement* is defined as the interaction that creates the shared meaning of norms and expectations. *Joint enterprise* is the engagement towards a common understanding of what the goal is. Lastly, *shared repertoire* refers to the resources, jargon, and objects used to negotiate meaning and facilitate learning (Biza et al., 2014; Li et al., 2009; Wenger, 1998).

Implications of Sociocultural Theories of Learning to this Dissertation

There are three main principles from these sociocultural theories of learning on which this study rests. The first of these is the idea that tools and organizational resources mediate the development of group and individual activity. This explicitly draws on the notion of mediation as described by Vygotsky. In this dissertation, the LS intervention will be considered a tool that is hypothesized to mediate how instructional team members (a) think about and discuss teaching

with one another, and (b) build a culture around teaching. As mentioned in Chapter 1, CHAT provides a useful framework that enables me to examine what is promoting or constraining how individuals engage in teaching and with one another. Figure 2.1 depicts an application of Engeström's (1999) activity triangle to this study. The subject of investigation will be the instructional teams who participate in LS. The main intervention will be the introduction of LS as a PD opportunity. The object (or goal) of participating in LS is to support student learning. By leveraging the idea of mediation, I can investigate in what ways LS supports the instructional team in achieving this goal.

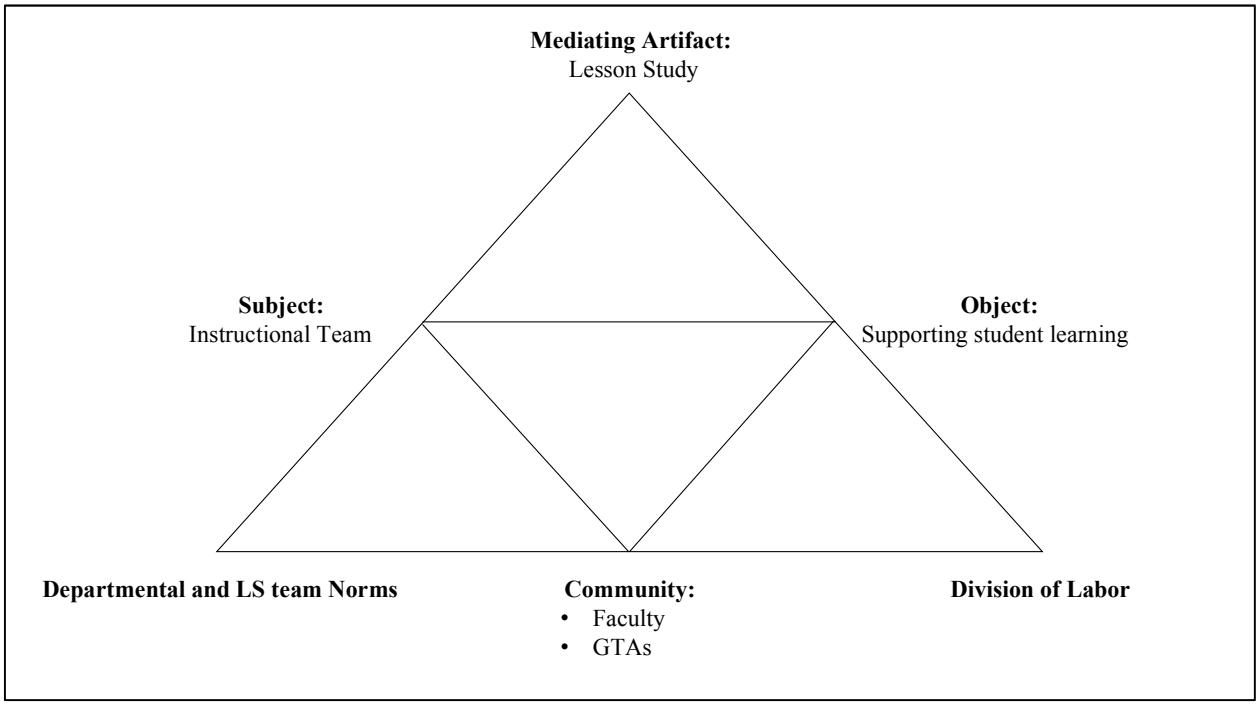

Figure 2.1: LS activity triangle

The second principle on which this study rests on is the dynamic nature of the individual components (i.e. community, division of labor, and norms) in an activity system. In other words, in order to understand how instructional teams engage with LS to support student learning, I must also pay heed to the community, division of labor, and norms that the instructional team take part in (Figure 2.1). Because the CHAT framework allows me to tease out what the norms

are of the community and how labor has historically been divided within STEM departments, I can investigate what factors outside of the LS intervention are impacting instructional teams' level of engagement. For instance, the notion of the research-teaching tradeoff (Shortlidge & Eddy, 2018) may imply certain roles that graduate students should prioritize (i.e. research over teaching), which may encourage or inhibit how graduate students engage in the LS. If GTAs acknowledge how their existing program structures communicate a devaluation of teaching, they may want to fully immerse themselves in the LS cycle as it is a rare PD opportunity. On the other hand, if GTAs endorse the research-teaching tradeoff, they may not fully commit to the LS process and see it as a hindrance to their research progress. This serves as one example as to how sociocultural theories of learning will provide a useful lens for data analysis.

The final sociocultural principle that guides this study is the idea that learning is a social endeavor that originates from participation and social interactions within a community. Because LS is a model that inherently promotes community and collaboration between team members, I will consider what instructional team members say and how these contributions culminate into shared knowledge and practice. Drawing explicitly on Wenger's (1998) three interrelated dimensions of a community, I can examine how mutual engagement may rewrite or establish new norms or system dynamics so that together, LS team members deepen their understanding of teaching. I can also investigate the formation of the joint enterprise and examine the ways the instructional team come to a common understanding of what teaching is. Lastly, analyzing the team's shared repertoire can inform what elements of LS are particularly useful or relevant for instructors in a higher education setting.

Linking Literature to Research Questions

I conclude Chapter 2 by presenting the empirical research and theory that underpin and motivate the three RQs investigated in his study.

RQ1: What teaching perspectives the instructional team operating from throughout the course of the LS?

As detailed in this chapter, LS has been attributed to changes in teacher beliefs (Cajkler et al., 2015; Collet & Peñaflorida, 2020; Dotger, 2011; Schipper et al., 2017; Widjaja et al., 2017). While scholars assert that changes in teacher beliefs arise from the opportunities to discuss and challenge existing beliefs (Collet & Peñaflorida, 2020; Widjaja et al., 2017), I seek to further characterize the ways in which certain LS structures and activities (i.e. phases, discussion prompts, interactions with other team members) may promote certain beliefs, assumptions, or values about teaching.

To examine this RQ, I draw on Collins and Pratt's (2011) Five Teaching Perspectives (5TP) Framework. According to this framework, there are five perspectives of teaching: (a) transmission, (b) apprenticeship, (c) developmental, (d) nurturing, and (e) social reform. The general model of teaching includes five elements: (a) the role of the teacher, (b) the purpose of the learner, (c) the content being taught, (d) the context of where teaching occurs, and (e) the ideals that underpin teaching (Pratt & Smulders, 2016). Each perspective can be distinguished based on the level of importance and commitment to certain elements.

When operating from a transmission perspective, an instructor commits to efficiently and accurately delivering content knowledge. When visualizing the teaching model, the transmission perspective underscores the importance on the elements of the role of teacher and the content being taught. In this way, learning occurs once learners are able to reproduce the content

knowledge that was relayed to them. Teaching strategies that are often implemented by instructors with a transmission perspective include the use of advanced organizers and immediately correcting incorrect answers.

When operating from an apprenticeship perspective, an instructor commits to socializing learners into a specific community, whether that be the community of higher education or a discipline-specific community. In the apprenticeship perspective, the teacher is inseparable from the content they teach because "teachers teach who they are, as much as what they know or can do" (Pratt & Smulders, 2016, p. 52). In other words, the content that is being taught is a way of being and a way of knowing. Therefore, when considering the teaching model, the teacher, content, and context is emphasized. Learning occurs when a learner can think, talk, act, and behave as if they are members of a community. Teaching strategies that reflect an apprenticeship perspective include modeling certain behaviors or qualities and making implicit knowledge and skills explicit and accessible for learners.

When operating from a developmental perspective, an instructor commits to helping learners develop a more complex way of thinking about content. In the developmental perspective, the relationship between learners and content is underscored. Instructors recognize that students come into the teaching and learning process with prior experiences and knowledge, which shapes how they think about and understand content. Learning occurs when a learner revises their cognitive structure to enhance their understanding about content. Therefore, an instructor must be aware of and activate learners' prior experiences and knowledge and provide scaffolds so that learners can connect and integrate their prior experiences and knowledge with more complex content.

When operating from a nurturing perspective, an instructor commits to providing support and encouragement to learners so they can become confident and self-sufficient. In the nurturing perspective, an instructor places importance on the relationship between the teacher and their learners. Instructors believe that a learner's self-concept is what can drive or inhibit learning; therefore, instructors must build trust, instill intrinsic motivation, and create positive associations with their students. Learning occurs when learners have the confidence within themselves to learn content and can attribute their success to their own effort and ability. Teaching strategies that are often implemented by instructors with a nurturing perspective include acknowledging learner efforts, celebrating successes, and providing feedback.

When operating from a social reform perspective, an instructor commits to transforming society through their teaching so that they can enact change beyond the classroom. In the teaching model, ideals are underscored. That is, rather than focus on the teaching and learning process that occurs in the classroom, an instructor considers the impact these interactions will have within society. Teaching becomes a political act and learning is a transformative process in which an instructor's agenda is passed on and upheld by learners. Teaching strategies that align with a social reform perspective include engaging in community-based assignments or projects that deepen learners' understanding of societal dynamics and providing learners with the opportunities to make decisions about their learning (i.e. choosing project topics or evaluation method).

The 5TP are summarized in Table 2.1. I am particularly drawn to the 5TP framework because of the emphasis that there is no single definition of what it means to be a good teacher (Pratt et al., 2001). Additionally, the 5TP framework recognizes that instructors can hold multiple teaching perspectives dependent on context and content (Pratt & Smulders, 2016).

Using such a framework enables a more fluid method to characterize how the instructional team talks about and understands teaching. Recognizing that the LS model promotes collaboration and discussion among team members, the findings from this RQ will shed light on how the different components of the LS model mediate certain teaching perspectives and contribute to the creation of a joint enterprise.

Table 2.1: Five teaching perspectives (Note: Adapted from "Development and use of the Teaching Perspectives Inventory (TPI)" by D. D. Pratt, J. B. Collins, & S. J. Selinger, 2001, In *annual meeting of the American Educational Research Association, Seattle Washington*, p. 3. Copyright 2000-2020 by Daniel D. Pratt and John B. Collins.)

Perspective	**Commitment to:**
Transmission	Efficiently and accurately delivering knowledge for learners to gain mastery of content
Apprenticeship	Socializing learners into a specific community
Developmental	Helping learners develop more complex or critical ways of thinking about a specific domain
Nurturing	Providing support and encouragement so learners can become confident and self-sufficient
Social Reform	Transforming society through teaching to enact social change beyond the learning environment

RQ2: What are the communities, division of labor, and norms that impact the ways the instructional teams engage in LS?

As highlighted by the different models of GTA development, graduate students receive a multitude of messages about their roles and responsibilities as teachers, which can be communicated through faculty supervisors, peers, or departmental structures (Beath et al., 2012; Brownell & Tanner, 2012; Gilmore et al., 2014; Zotos et al., 2020). For RQ2, I use the CHAT triangle to guide my examination in investigating how activity components (i.e. community, division of labor, and norms) encourage or constrain the instructional team's participation in LS

or how LS may promote changes in the activity components. While empirical research suggests that LS strengthens teachers' sense of community (Cajkler et al., 2015; Huang & Shimizu, 2016; Lewis et al., 2006; Lieberman, 2009), findings from this RQ may illuminate the model's potential in promoting broader organizational and cultural change.

RQ3: What design features support the implementation of LS with higher education instructional teams?

Researchers over the past several decades have called for significant reform for GTA PD (Gardner & Jones, 2011; Korpan, 2014; Ridgway et al., 2017), pointing out that existing models and PD structures are insufficient in preparing GTAs for their roles. LS is an approach that has been heavily studied in the K-12 setting and that has a promising application to the higher education context. The literature surrounding LS in higher education is very limited. Many of the challenges experienced and reported by Dotger (2011), Demir et al. (2013), and Bickerstaff et al. (2019) arise from the contextual constraints associated with teaching in higher education. In particular, for this RQ, I will leverage the idea of mediation to examine the structures, activities, and discussion prompts that facilitate learning and engagement in LS. The findings from this RQ offer applicable insights for future LS facilitators and researchers who seek to implement LS with higher education instructional teams.

Chapter 3: Methods

The goal of my dissertation is to ultimately assess the impact and usability of LS as a PD model for higher education instructional teams. In summer 2021, I implemented a modified LS model to work and learn alongside two instructional teams. This chapter describes the methods I employed in this study. I divided this chapter into five main sections. First, I describe the methodological framework that guided the design of this study. Second, I provide an overview of the study context including the setting, participants, and LS model that was implemented. Third, I discuss what data I collected for my study and how I obtained these data sources. Fourth, I detail my data analysis process for each research question. Finally, I end my chapter by discussing my approach to ensuring reliability and validity of my analysis.

Methodological Framework and Design

Methodological Framework: Design-Based Research

For this dissertation, I employed Design-Based Research (DBR). DBR is a methodology that has evolved to bridge the gap between researchers and practitioners in the education community. Prior to DBR, curriculum was developed based on theoretical perspective, then disseminated and implemented into classrooms (Prediger et al., 2015). This unidirectional model often resulted in the unsuccessful implementation of curricula because of the lack of consideration for educational contexts and actors (i.e. teachers and students) within these contexts. DBR rose as the bidirectional alternative that more eloquently united instructional design and educational research.

A DBR framework enables researchers to purposefully and systematically design a learning environment or instructional intervention with the intent of exploring phenomena that emerge within the setting and among the participants (Design-Based Research Collective

[DBRC], 2003; Prediger et al., 2015). My goal for using this methodological approach is to extend on theoretical claims about GTA PD and refine design principles in order to pragmatically address the demands of authentic learning environments. There are five main features of DBR: (a) an intervention is introduced, (b) background theory is interwoven into the design process, (c) the research process is iterative, (d) the research is situated in the learning context, and (e) concrete products and theories emerge from the research to inform researchers and practitioners (DBRC, 2003; Prediger et al., 2015).

Intervention is Introduced

The first feature of DBR is that the research introduces a new form of instruction to an educational setting (Prediger et al., 2015). In this dissertation, I introduced the modified LS model to the instructional teams, meaning the LS model is the intervention. A DBR methodology is uniquely advantageous when studying an intervention because it allows researchers to explore the impact that different activities, discussion prompts, and tasks have on their intervention. This DBR feature serves as the motivation for RQ3.

Background Theory is Interwoven into the Design Process

The second feature of DBR emphasizes the importance of designing a learning environment based on theories of learning (Prediger et al., 2015). As described in Chapter 2, this study is designed with a sociocultural theory of learning lens. One assumption driving this work is that engagement in LS will serve as a mediating activity for the instructional teams in their development as instructors. Furthermore, the modified LS cycle implemented in this study was informed by both existing sociocultural theories of learning and teacher and GTA PD (Confrey, 1995; Gardner & Jones, 2011; John-Steiner & Mahn, 1996; Nyquist and Sprague, 1998; Wenger,

1998), as reviewed in Chapter 2, as well as the educational context being studied, as will be discussed in Chapter 6 when describing the findings for RQ3.

Research is Iterative

The third feature of DBR is that research is an iterative and retrospective process. In other words, research is a continuous cycle of design, enactment, analysis, reflection, and redesign (DBRC, 2003; Prediger et al., 2015). After an intervention is enacted, the analysis of its impact and reflection on the events that occurred informs the revisions of the design for the next round of implementation. The LS models enacted in this dissertation were integrated with two instructional teams with staggered starting dates. Additionally, each instructional team completed at least two modified LS cycles. The data collected from this study were analyzed and reflected upon in ways that informed subsequent LS cycles during the study period, as well as design modifications for future iterations (RQ3).

Research is Situated in the Learning Context

The fourth feature of DBR is that the research is situated within a learning context. This feature allows for researchers to account for the complexity of real learning environments and make meaningful conjectures and innovations for implementation and application by practitioners and policy makers (DBRC, 2003; Prediger et al., 2015). The learning context in this dissertation is the weekly instructional team meetings where LS activities and discussions took place, which is the main data source for the findings reported in this study.

Research Produces Concrete Products and Theories

The final feature of DBR is that the research results in two distinct products: (a) designed innovations that enhance learning, and (b) proposed theories about teaching and learning (DBRC, 2003; Prediger et al., 2015). The most apparent innovations that are produced from

DBR include the intervention and new forms of instruction which practitioners can implement. However, by engaging in DBR, researchers can also articulate expected or unexpected results that occurred throughout the design, enactment, and analysis process, thereby also producing theories of learning. From this dissertation, I will not only suggest design features (RQ3) for implementing LS with higher educational instructional teams (i.e. generation of innovation), but also examine the ways in which LS supports the learning of the instructional team (RQ1 and RQ2) (i.e. generation of proposed theories of teaching and learning). Figure 3.1 depicts the applications of the DBR features to my study design.

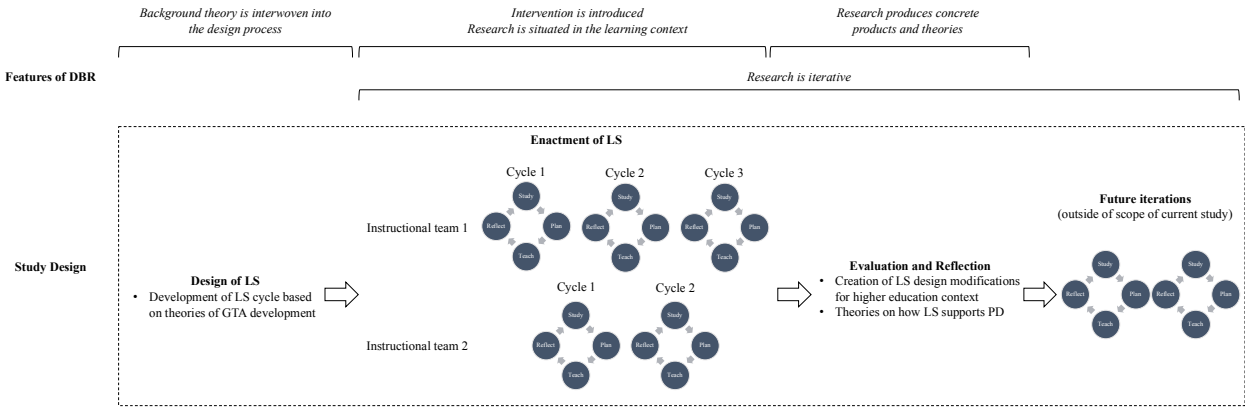

Figure 3.1: Application of DBR to study design

Study Context

In this section, I describe the study setting and the demographic information of the study participants. Then, I detail the logistical aspects of the enactment of LS model and provide an overview of the activities the instructional team engaged in.

Setting and Participants

This study took place at a public, four-year, Hispanic-serving institution in California. Data was collected during summer 2021, in the midst of the COVID-19 pandemic. The LS was

implemented in a virtual setting using Zoom videoconferencing services and Google Suite. Access to these web-based services were provided by the institution of study.

Eight participants were recruited using a combination of Patton's (1990) purposeful and convenience sampling. There were two instructional teams that participated in the study. Two of the participants were in an authoritative role: one instructor served as the instructor of record for both courses (Prof. Martin), and the second instructor served as the department lab coordinator (Prof. Johnson). The remaining six participants were GTAs enrolled in a graduate chemistry program at the institution of study. The lab coordinator was recruited for this study per the request of the instructor of record, but only attended two sessions. The sample was purposeful in that the course instructor who was recruited was teaching a high enrollment STEM course and interested in collaborating with her GTAs over teaching and instructional design. The sample was also convenient because the lab coordinator and GTAs who agreed to participate in this study were assigned to the courses as determined by department placement.

The instructional team for Course 1 consisted of the course instructor of record, two GTAs, and the lab coordinator. Course 1 denotes that this instructional team taught the first course in the introductory chemistry lecture and lab course series. Course 1 took place over an eight-week summer session term. The Course 1 instructional team had seven LS meetings. Prof. Johnson attended LS meetings four and five.

The instructional team for Course 2 consisted of the course instructor of record, four GTAs, and the lab coordinator. Course 2 denotes that this instructional team taught the second course in the introductory chemistry lecture and lab course series. Course 2 took place over a six-week summer session term. The Course 2 instructional team had five LS meetings. Prof. Johnson attended LS meetings two and three.

Due to the small number of study participants, I have chosen to only disclose aggregated demographic information to reduce the risk of potentially revealing participants. All participants identified as women. I have chosen not to disclose the racial and ethnic identities of the participants in order to protect their confidentiality as this dissertation reports its findings using pseudonyms and transcript excerpts. The participating GTAs were either enrolled in a master's or doctoral program at the time of data collection. The number of previous academic terms that the GTAs have worked with Prof. Martin range from zero to eight terms. The GTAs' prior teaching PD experiences varied; while some GTAs had no prior teaching PD, the most extensive PD some of the GTAs engaged in was taking a semester-long scientific teaching and learning course provided by the department. The instructor of record and lab coordinator were not compensated for their participation in the study. The GTAs received monetary compensation for their time, which was calculated using the minimum wage rate as determined by California state laws during the time of data collection.

Enactment of LS

Both instructional teams engaged with LS over the course of their respective summer sessions. Course 1 instructional team had 7 meetings and engaged in three LS cycles. Course 2 instructional team had 5 meetings and engaged in two LS cycles. Figure 3.2 depicts the LS timeline for both instructional teams. LS meetings occurred during the weekly instructional team meetings scheduled by Prof. Martin. On average, meeting times were approximately 90 minutes. The first 30 minutes were dedicated to Prof. Martin discussing logistical details about the upcoming lab procedures and lecture content. The remaining 60 minutes of each meeting were dedicated to LS activities. Meetings were held virtually and recorded using Zoom videoconferencing software.

I used the facilitator guide found in Appendix A to facilitate LS meetings. This guide was adapted from LS practitioner guides that were tailored towards K-12 teachers (Lewis, 2002b; Stepanek et al., 2007). Following DBR principles, I modified the activities for the higher education context based on existing theories and research on GTA PD as reviewed in Chapter 2.

In the following subsections, I provide a basic outline of the activities and prompts that were planned in the facilitator guide, but the full guide can be found in Appendix A. Changes to the guide that were made in response to the instructional team and the learning context are described in Chapter 6 as the decision-making process behind these changes culminated in the formation of design features.

	June 21-25	June 28-July 2	July 5-9	July 12-16	July 19-23	July 26-30	August 2-6
Course 1 instructional team	Establish norms and develop research theme	Cycle 1: Study and Plan	Cycle 1: Teach and Reflect	Cycle 2: Study and Plan	Cycle 2: Teach and Reflect	Cycle 3: Study and Plan	Cycle 3: Teach and Reflect
Course 2 instructional team			Establish norms and develop research theme	Cycle 1: Study and Plan	Cycle 1: Teach and Reflect	Cycle 2: Study and Plan	Cycle 2: Teach and Reflect

Figure 3.2: LS timeline

Establishing Norms and Expectations

Establishing norms and expectations is an important step in the LS process as it is the team's first collective effort together. Considering that norms in the U.S. portray teaching as an individual activity (Darling-Hammond & McLaughlin, 2011) and GTAs are often not given the opportunity to engage in the scholarship of teaching and learning (Gardner & Jones, 2011; Schussler et al., 2015), the establishment of norms and expectations allows members of the instructional team to reexamine their own beliefs about the culture and practices of teaching and learning and feel motivated to take teaching risks within the comfort of a safe space (Lewis & Hurd, 2011).

In my first meeting with each instructional team, the first activity we engaged in was establishing group norms and expectations. Each member of the instructional team, including me as the facilitator, was given a designated slide in a Google Slides deck to create a collage of pictures, words, and quotes that represent the type of dynamic and community they want for the team. After engaging in the activity and sharing their slide, examples of group norms from the LS practitioner guides (Lewis, 2002b; Stepanek et al., 2007) were presented and instructional teams were invited to modify the existing lists (i.e. add, remove, or reword) based on the previous activity. To ensure that the norms and expectations were being upheld throughout the course of the PD, I included a question in the weekly reflection forms that GTAs completed after every meeting asking if they perceived the norms were maintained that week. The responses to the weekly reflections were only viewable by me and were used to inform the facilitation strategies I implemented in future meetings.

Developing Research Themes

In the first meeting, the instructional teams also developed their research themes. Research themes are broad, long-term goals that the team holds for their students. The instructional teams were tasked with identifying two themes: a student development theme and an equity theme. The student development theme is a goal for students regarding their development as learners in higher education (e.g. “developing independent thinkers” or “building a desire to learn”). Modified from the California Action Network for Mathematics Excellence and Equity (CANMEE, 2019) model of LS, the equity theme is a goal the LS team may have that addresses equal opportunities for access and success (e.g. “building a sense of agency in students’ career paths” or “validating students’ STEM identities”). Both the student development theme and the equity theme served as a guide for the instructional teams throughout their LS

process. Developing research themes at the beginning of the LS cycle reflect a backwards design framework (Wiggins et al., 2005) in which participants start with goals to inform decisions about lesson plans.

To begin developing the research themes, I invited instructional teams to examine their department website's welcome statement and individually reflect on the ideas that are salient and missing from the welcome statement. While the activity was originally planned to examine the department's mission and vision statements, I opted to use the department's welcome statement because there was no publicly available mission and vision statements. After individual reflection, a group discussion allowed members of the instructional team to collectively brainstorm and develop their research themes. The instructional team for Course 1 decided upon the following research themes:

> *Student development theme*: Students will develop chemistry knowledge and critical thinking skills, not just memorize concepts. Students will use course concepts to engage with the material and the world around them.
>
> *Equity theme*: Students will build their collaboration with one another and build their STEM identity by relating the course to their degree outcomes. (Course 1, Brainstorm document)

The instructional team for Course 2 decided upon the following research themes:

> *Student development theme:* Students should be able to be independent scientists who can think critically and leverage their resources to find the information they need instead of expecting everything to be given to them on a silver platter.
>
> *Equity theme:* Students should be able to build the confidence to stay resilient when faced with challenging problems, and students will be able to access the material, especially disciplinary terminology. (Course 2, Brainstorm document)

At the beginning of every LS meeting, I presented the research themes to ground our discussions and activities for the day.

Study Phase

The study phase is critical to the LS process as it builds a resource that team members will draw from when planning, teaching, and reflecting on the lesson. In the study phase, teams will often examine existing instructional materials, student misconceptions, and the course sequence of concepts in order to understand what may impact a student's learning trajectory (Takahashi et al., 2005). By engaging in this practice, LS remains a model centered around student thinking.

When recruiting Prof. Martin to participate in my study, we negotiated a two-week LS cycle where the lessons that would be the focus of the LS were already decided upon based on the lab experiments scheduled for each course. The lesson topics that served as the focus for Course 1 cycles were: (a) valence shell electron pair repulsion (VSEPR) theory for cycle 1; (b) identification of an unknown metal carbonate for cycle 2; and (c) the nature of science for cycle 3. The lesson topics that served as the focus for Course 2 cycles were: (a) limiting reagents for cycle 1; and (b) freezing-point depression for cycle 2.

Recognizing that lab experiments are non-negotiable because these procedures are determined at the departmental level, Prof. Martin requested to focus our LS cycles on the introduction of each focal lab. The introduction of each lab consisted of GTAs reviewing the scientific knowledge and skills necessary to complete the lab for that day. This typically occurred in the first 10-15 minutes of the lab section. Additionally, Prof. Martin wanted to focus on challenging GTAs to situate the scientific concepts of the lab to real-world examples in order for the students to see chemistry in their daily lives.

The study phase for each LS cycle began with the invitation for instructional team members to reflect on their own teaching and learning experiences with the lesson topic. For

example, an individual reflection prompt would read: “Reflect on your time as a student first learning about VSEPR theory or your first time teaching VSEPR theory. Were there certain concepts or constructs that were confusing or difficult to grasp? What were they? Why do you think they were confusing or difficult to grasp?” After allowing for individual reflection, I facilitated a group discussion that allowed each member of the instructional team to share their experiences with the topic. After the group discussion, I brought in education research literature or published student work samples that represented common misconceptions and different learning trajectories for the topic. The outside resources I brought into the meeting often corroborated with the ideas and experiences that were shared in group discussion. The knowledge gained from personal experiences, other team members, and outside resources served as the groundwork for planning the lesson.

Plan Phase

The plan phase focuses on structuring a lesson with tasks and prompts that will equitably and effectively engage students in the material. Lesson ideas and activities should consider the different ways students may think about the topic and provide students with the support to gain the expected knowledge and skills. Engagement in this practice enables the instructional team to confront the beliefs and assumptions they hold about the content, student thinking and learning, and lesson planning (Lewis & Hurd, 2011).

As mentioned above, the lesson for the plan phase was limited to the 10-15 minute introduction of the scientific concepts necessary for the focal lab experiments. To engage in the planning process, I reminded the instructional teams of their research themes in order to ground the lesson in the broader goal of the whole PD process. Additionally, I had them consider the lab instructions and, based on the knowledge gained from the study phase, had the team identify the

areas or steps that may surface any misconceptions or confusions. By engaging in this practice, the GTAs discern what scientific concepts to emphasize in the introduction. Finally, because of Prof. Martin's request to spotlight the scientific concepts in real-world contexts, the GTAs were asked to consider what examples they could use to introduce students to the topic.

Lesson ideas were documented on a running brainstorm document on Google Docs. Traditional LS requires teams to create a detailed lesson plan which contains the activities that students would be engaging in, the prompts that the teacher poses to students, and the expected student reactions or responses to the activities and prompts. Additionally, the lesson plan also highlights moments in the lesson that the team will use to document evidence of student learning and assess student progress (Stepanek et al., 2007). The lesson plan serves as a guide for the teacher who teaches the lesson and the team members who observe the lesson. The instructional teams in my dissertation did not create detailed lesson plans, as similarly reported by Dotger (2011), but the running brainstorm document served as a locus that unified and prepared the GTAs for the teach phase.

Teach Phase

The teach phase is a feature of LS that sets this model apart from other PD approaches because it enables teams to put their newfound knowledge and theory of learning into practice (Lewis, 2002a). In addition to teaching the lesson, the teach phase also requires other instructional team members to gather data on how students respond to their planned activities and prompts in order to gain insight into student thinking. Understanding student thinking equips instructors to better foster student learning (Franke et al., 1998).

Because all GTAs had at least one lab section to lead in their respective courses, all GTA members of the instructional team implemented the activities and prompts that were planned in

the plan phase. In the LS meeting before the focal lab, one GTA volunteered to record the interactions they had with students in the 10-15 minute introduction. As labs were conducted virtually for the academic terms, these teaching segments were recorded via Zoom videoconferencing software.

In the LS meeting after the focal lab, the instructional teams watched the recording of the lesson together. I provided an observation guide for members of the instructional team to use while watching the recording. The observation guide integrated characterization systems from existing observation protocols, such as the Classroom Observation Protocol for Undergraduate STEM (Smith et al., 2013) and the Classroom Discourse Observation Protocol (CDOP; Kranzfelder, 2019). I will elaborate on the content and modifications of the observation guide used in the teach phase in Chapter 6. The evolution of the observation guide over the course of the PD illustrates the ways in which I modified LS activities in response to the ideas and behaviors of the instructional teams.

Reflect Phase

The nature and purpose of the reflect phase is to support the instructional team in identifying what they have learned throughout the LS cycle (Lewis & Hurd, 2011). To facilitate the reflection, I first began with a debrief of the lesson recording. Following a debrief discussion sequence often used in traditional LS, the GTA whose lesson we watched was first invited to share their experience about teaching the lesson, noting any successes or challenges they encountered. After, the rest of the instructional team were invited to share their thoughts and ideas on the lesson, grounding their comments in evidence from the teaching recording. As the facilitator, I would save my comments until the end of the debrief.

After the debrief, the discussion shifted towards considering the instructional teams' next steps in the learning process. The traditional LS model encourages team members to consider the concrete revisions they will make to the lesson or ponder how their new insights can inform future lessons. Since subsequent LS cycles in this study would not focus on the same content or lab, I did not ask the instructional teams to modify their lesson. Instead, members of the instructional team were asked to identify at least one takeaway from the LS cycle that they will implement in their future teaching. The instructional teams were also prompted to consider what new questions they have about teaching and learning that may have been uncovered from the LS cycle, as well as what teaching strategies implemented in the future would shed insight into these questions. The takeaways, new questions, and suggested teaching strategies were revisited and emphasized in subsequent LS cycles.

Reflect on LS Process

At the final meeting with each instructional team, I also facilitated a reflection on the entire LS process. This segment allowed members of the instructional team to reflect on what aspects of LS were useful or challenging. Additionally, team members were asked to articulate how the LS discussions and activities have shaped the way they think about teaching and learning.

Data Sources

I collected four main forms of data: field notes, meeting recordings, LS artifacts, and individual interviews with the GTAs from the instructional teams, as detailed next.

Field Notes

Serving as both researcher of this study and facilitator of LS, I documented my thoughts, ideas, feelings, successes, and challenges, which generated field notes throughout the study.

Field notes serve as a way for researchers to record their way of being in their research and track how this impacts the course of their study (Mills & Morton, 2013). Field notes are also a method to combine empirical detail with personal interpretations and impressions (Emerson et al., 1995). The generation of field notes took two different forms. For the recruitment of study participants and preparation of original facilitator guide, field notes were written on a running Microsoft Word document. Once LS was underway with both instructional teams, field notes were recorded in a solo Zoom videoconferencing room and the recording transcript was obtained. Both forms of field notes were uploaded to MAXQDA Analytics Pro (VERBI Software, 2016), which is a qualitative analysis software. Keeping an archive of my interpretations of my experiences were particularly important because of my dual role as researcher and LS facilitator, as is elaborated on in Chapter 7. My interpretation of the moments and interactions that occurred in the study guided what I explored and analyzed as a researcher, as well as what I choose to modify as LS facilitator.

Meeting Recordings

Each of the meetings with the instructional teams were recorded through the Zoom videoconferencing software, where recording transcripts were downloaded, edited to improve accuracy of the transcript, and uploaded into MAXQDA Analytics Pro. The chat text within Zoom was also saved in order to capture any contributions that were made using that format.

LS Artifacts

Throughout the LS process, each instructional team had their running brainstorm document and personalized slide decks which documented their thoughts and ideas. Additionally, after every meeting each GTA from both instructional teams filled out a weekly reflection form which served as a way to: (a) determine if group norms were being upheld; (b)

take note of the most salient ideas from the meeting; (c) note down any questions that remain or were emerged from the meeting; and (d) document any change in thinking about teaching and learning. Structure of the reflection form was modified from Barlow et al. (2020). The complete reflection form can be found in Appendix B. The brainstorm document, personalized slide decks, and weekly reflections were valuable sources of information as they provided insight to the learning trajectory of the instructional team through the PD.

Individual Interviews

The GTA participants of this study also engaged in a a post-participation interview which occurred within two weeks after the last LS meeting. I facilitated 60-minute individual, semi-structured interviews with each GTA (Bernard, 1988). The semi-structured format enabled each GTA to further elaborate on salient ideas and moments within their responses, and it also allowed me to pursue leads that were unique to each GTA's response.

There were two sections of the interview protocol. The purpose of the first set of questions was to gauge how the GTAs experienced LS. In addition to asking about their perceived benefits and challenges, I presented the GTAs with all the phases of LS and prompted them to consider how discussions and activities in each phase impacted their thoughts about and approaches to teaching and learning. The purpose of the second set of questions was to gain insight into how the GTA conceptualized their role and responsibilities as a TA. These questions were modified from an existing interview protocol (Prosser et al., 1994). While only interview responses from the first set of questions were used for data analysis in this dissertation, the full interview protocol can be found in Appendix C.

Data Analysis

In this section, I describe the data analysis procedures for each RQ.

RQ1: What teaching perspectives are the instructional team operating from throughout the course of the LS?

To answer this research question, I utilized a case study approach (Yin, 2018) and analyzed data sources from Course 2 instructional team. By solely focusing on the Course 2 instructional team for this research question, I am afforded the opportunity to describe the LS process from their teaching perspectives. To present the findings in Chapter 4, I employ an ethnographic case study (Schwandt & Gates, 2018) to chronologically detail the activities, discussion, and events that occurred during their LS process in an effort to build an argument about how LS promotes certain perspectives of teaching. My field notes, the meeting recordings, and the LS artifacts generated from the Course 2 instructional team were analyzed for this RQ.

Transcripts from meeting recordings and LS artifacts generated from Course 2 instructional team meetings were *a priori* coded using the Five Perspectives on Teaching framework (Collins & Pratt, 2011), as summarized in Table 2.1, in order to determine what teaching perspectives the instructional team were operating from when they engaged in the different phases of the LS process. The full codebook I used to analyze the data the data can be found in Appendix D. I uploaded transcripts and all LS artifacts to MAXQDA Analytics Pro for analysis. Meeting transcripts were segmented for codes in two ways: (1) by talk turn for each individual contribution to the discussion, then (2) by shifts in ideas. This segmentation practice allows for one talk turn to be coded for multiple perspectives.

RQ2: What are the communities, division of labor, and norms that impact the ways instructional teams engage in LS?

I used all four data sources (i.e. field notes, meeting recordings, LS artifacts, and post-participation interviews) for both instructional teams to answer this second RQ. I uploaded all

data sources to MAXQDA Analytics Pro for analysis and used a five-step coding process as detailed in Figure 3.3a. Ideas and phrases found in the data sources were first categorized according to which system aspect, as defined by CHAT (Engeström, 1999), was mentioned or implied (i.e. community, division of labor, norms). Ideas and phrases that included multiple system aspects were placed in all relevant categories. Then, I used a thematic analysis approach (Braun & Clarke, 2006), to develop initial inductive codes that described the nature of each system aspect. An initial codebook was developed, and similar codes with overarching themes were collated. From this first step of coding, I identified a pattern that suggested there were two systems that the instructional teams were navigating: the LS system and the department system. These two systems served as higher-level categories in the codebook. In order to develop a robust codebook, I reviewed the coded data to make sure the codes were accurately and clearly describing the idea. Once the final codebook was developed, I re-read all data sources to ensure that additional important ideas were not overlooked. Finally, I compared the codes across the different aspects of the system and across both systems to build an understanding of how they relate to one another. An example of this analysis process is summarized in Figure 3.3b.

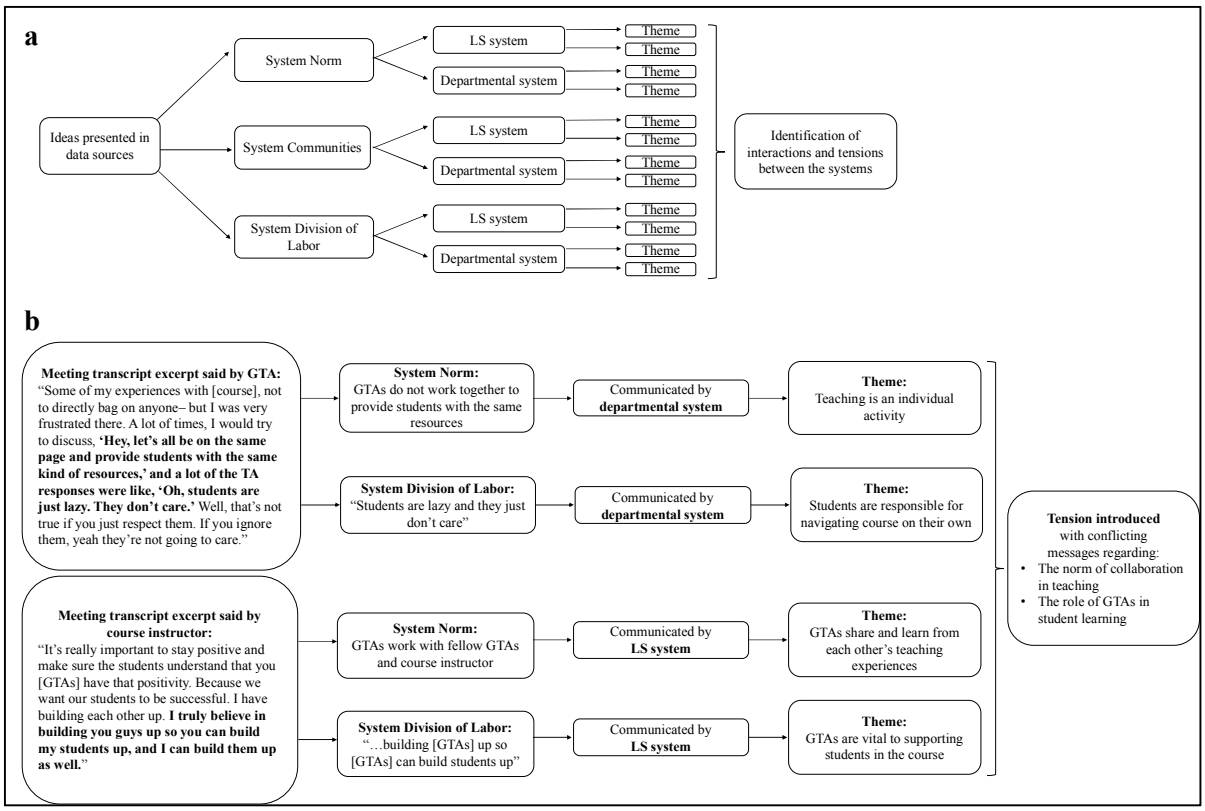

Figure 3.3: RQ2 coding process

RQ3: What design features support the implementation of LS with higher education instructional teams?

With a commitment to DBR, my third RQ is focused on suggesting and highlighting design features within the LS model to promote its use in higher education. I uploaded field notes, meeting recordings, and LS artifacts into MAXQDA Analytics Pro and used thematic analysis (Braun & Clarke, 2006) in order to inductively code for (a) modifications I intentionally and unintentionally made throughout the PD, and (b) how these modifications impacted engagement with LS. Following the comparison approach presented by Norwich et al. (2021), I first highlight in what ways my modified LS differ from the traditional LS model. Then, following Zahner et al.'s (2021) methods for introducing and illustrating design features, I draw

on both existing theory in the literature, as well as evidence from my data sources, to provide evidence for why I chose to highlight these design features.

Reliability and Validity

Reliability and validity are often concerns that scholars have when employing a qualitative study (Yin, 2018; Miles et al., 2020). To enhance the reliability of my analysis process and my findings, I engaged in constant data comparison and comprehensive data use (Silverman, 2009). With constant data comparison, I continuously evaluated my interpretations of previously coded data with newly coded data (Corbin & Strauss, 1990), which allowed me to confirm or disconfirm conjectures I made about the data. The constant data comparison process helps to (a) guard against any biases that I bring to the analysis process; (b) produce more precise and accurate analytical codes and themes; and (c) maintain consistency across my data. Additionally, I used multiple data sources to answer each of my research questions, which support my engagement in comprehensive data use. Thus, I am able to triangulate my findings by using evidence from different data sources.

Maxwell (2013) identified five threats to validity in qualitative research: (a) descriptive validity, (b) interpretation validity, (c) researcher bias, (d) theory validity, and (e) reactivity. Descriptive validity refers to how accurate data is collected. Maxwell (2013) describes how tape or video recordings can sometimes fail to describe certain environmental factors or feelings that may have influenced a specific moment in time. My detailed field notes about every encounter and meeting associated with my dissertation serves as one method to combat the descriptive validity threat because I took note of the feelings and actions that may have been overlooked when simply reading a meeting transcript. These field notes were important in understanding the data during the analysis process.

Interpretation validity refers to how accurately a researcher captures a study participant's perspective and interpretation (Maxwell, 2013). Mainly referring to analysis of interview data, the primary threat to valid interpretation is when I may be imposing my own understanding onto something a GTA said in their interview. To combat this threat, I purposefully chose to conduct semi-structured interviews so that I could follow-up on certain ideas and GTAs could further elaborate on their responses (Bernard, 1988).

Researcher bias refers to the unintended outcomes in the analysis process that are attributable to a researcher's pre-conceived beliefs or expectations. In order to address this threat to validity, it is first important to acknowledge my positionality. As a former TA and current graduate student interested in disrupting the norms and structures introduced and perpetuated by Western hegemonic discourse, I recognize that my personal experiences and expectations for conducting this study may impact the study outcomes. To mitigate the impact of my biases, I met regularly and worked closely with national and international LS researchers throughout my data collection and analysis process. Additionally, I presented preliminary findings at several conferences before writing this dissertation (Suarez, 2021a; Suarez, 2021b; Suarez, 2021c; Suarez, 2021d). Both of these practices gave me access to reflective partners (Prediger et al., 2015) who challenged my interpretations of the data and provided new perspectives and interpretations of the data.

Theory validity refers to the degree to which the data collected supports the findings reported. To combat this validity threat, I am include a large number of interview excerpts into my results chapters as evidence for my claims. By including these excerpts, I offer readers the opportunity to make their own interpretations of my data and accurately represent the voices of my participants.

Finally, reactivity refers to the risk of obtaining study results that artificially resulted in response to the presence of the researcher or the study context. This is a particularly important validity threat to consider because I served as both researcher and LS facilitator for my dissertation. Recognizing that reactivity threat is impossible to control for (Maxwell, 2013), I purposefully engaged in the activities and discussions alongside members of both instructional teams when establishing norms and expectations. By doing so, I intended to build trust with the instructional team and position myself as a fellow learner. Additionally, in the individual post-participation interviews, I prefaced the interview by including a statement on how LS is a traditionally K-12 PD model and not much has been explored in the higher education setting. I reassured GTAs that their responses will provide necessary insight into determining how feasible LS is for the higher education setting. Such statements were interjected throughout the interview if GTAs were hesitant about responding to a question. By using these statements, I intended to position GTAs as pioneers for this research and to invite them to respond with complete honesty.

Chapter 4: Teaching Perspectives during LS

In this chapter, I present the findings for RQ1: *What teaching perspectives are the instructional team operating from throughout the course of the LS?* Leveraging the 5TP framework (Collins & Pratt, 2011), I first discuss the broad findings of my analysis by highlighting the frequency count and total time spent verbally communicating ideas related to each perspective in LS meetings for Course 2 instructional team. A recap of the 5TP can be found in Table 4.1. The full coding guide can be found in Appendix D.

After presenting these general findings, I use an ethnographic case study approach (Schwandt & Gates, 2018; Yin, 2018) to chronologically recount the course of the PD, describing the context and detailing the occurrences of every meeting. I opted for using a case study approach in order to highlight how a wide range of factors (e.g. contributions of individual team members, context of teaching and learning in a virtual environment, my role as a facilitator, and LS activities and prompts) may impact the teaching perspectives taken on by the instructional team.

Table 4.1: Five teaching perspectives. (Note: This is a reproduced version of Table 2.1)

Perspective	**Commitment to:**
Transmission	Efficiently and accurately delivering knowledge for learners to gain mastery of content
Apprenticeship	Socializing learners into a specific community
Developmental	Helping learners develop more complex or critical ways of thinking about a specific domain
Nurturing	Providing support and encouragement so learners can become confident and self-sufficient
Social Reform	Transforming society through teaching to enact social change beyond the learning environment

Overview of Findings

Frequency Count of Ideas Conveying each Teaching Perspective

I first determined the frequency count of each coded perspective throughout the five-week summer academic term, which contained one meeting to establish norms and develop research themes, as well as two LS cycles (see Figure 3.2 for PD timeline). Table 4.2 provides the frequency count of each coded perspective in relation to the total number of teaching perspectives per LS phase (i.e. table rows) and over the entire course of the five-week PD (i.e. table columns). In addition to providing the frequency count, I layered on a shaded heat map to visually depict which perspectives appeared at a higher frequency (i.e. darker shades) and which perspectives appeared at a lower frequency (i.e. lighter shades) in relation to the total number of teaching perspectives over the five-week PD.

Overall, the developmental perspective appeared the most over the course of the five-week PD (approximately 37% of total codes). The second and third most perspectives that appeared were transmission (approximately 30%) and nurturing (approximately 23%), respectively. The apprenticeship perspective was the second least frequent (approximately 12%), while the social reform perspective did not appear at all.

When establishing norms, there were four instances where a nurturing perspective was communicated to the group and one idea that conveyed a transmission perspective. When developing a research theme, the instructional team shared a large number of ideas related to the apprenticeship perspective (11 counts) and a smaller number communicating the nurturing perspective (4 counts). In the first LS cycle, the developmental perspective appeared the most frequent (13 counts) during the study phase, with ideas from the transmission perspective (7 counts) and nurturing perspective (5 counts) also appearing to a lesser extent. During the plan

phase, the transmission perspective appeared the most frequent (14 counts), the developmental perspective appeared the second most frequent (13 counts), and the apprenticeship (3 counts) and nurturing (2 counts) perspectives appeared to a lesser extent. During the reflect phase, the transmission (6 counts) and nurturing perspectives (6 counts) appeared the same amount, while the developmental perspective appeared at a lower frequency (3 counts).

In the second LS cycle, the transmission perspective appeared the most frequent (4 counts) during the study phase, with ideas from the developmental perspective also appearing at a similar frequency (3 counts). The nurturing perspective also appeared during the study phase but at a lower frequency (1 count). During the plan phase, the developmental perspective appeared the most frequent (5 counts) and the transmission perspective appeared to a lesser extent (2 counts). During the reflect phase, the developmental perspective also appeared the most frequent (7 counts); the nurturing perspective appeared the second most frequent (5 counts), while the transmission perspective appeared at a much lower frequency (1 count).

The pattern of the frequency counts may raise a couple of questions related to the reasons why certain codes appear more or less frequent, the disappearance of the apprenticeship perspective, the complete absence of the social reform perspective, and the general tapering of teaching perspectives codes in the second LS cycle. I suggest reasons for these patterns when documenting the case study, which appears later in this chapter.

Table 4.2: Frequency count for teaching perspectives

		Transmission	Apprenticeship	Developmental	Nurturing	Social Reform	**Total Codes per Phase**
Week 1	Establish Norms	1			4		**5**
	Development of Research Theme		11		4		**15**
Week 2	Study	7		13	5		**25**
	Plan	14	3	13	2		**32**
Week 3	Reflect	6		3	6		**15**
Week 4	Study	4		3	1		**8**
	Plan	2		5			**7**
Week 5	Reflect	1		7	5		**13**
Total codes per perspective (% total out of all codes)		**35** (29.2%)	**14** (11.7%)	**44** (36.7%)	**27** (22.5%)		**120**

Time Spent Discussing Ideas Related to each Teaching Perspective

While frequency count of each teaching perspective provides insight into what types of ideas were raised during the LS meetings, I also wanted to offer a different lens into the content of the meetings by providing the percentage of time the instructional team spent verbally communicating ideas related to each teaching perspective. Table 4.2 provides information related to the amount of time a certain perspective was discussed and communicated in meeting discourse. The total amount of time spent in meetings throughout the five-week PD was approximately 300 minutes. Approximately 33% of coded meeting time was spent discussing ideas related to the developmental perspective. Approximately 30% of coded meeting time was spent discussing ideas related to the apprenticeship perspective. Approximately 20% of coded meeting time was spent discussing ideas related to the nurturing perspective. Finally, approximately 17% of coded meeting time was spent discussing ideas related to the transmission

perspective. There was no time spent discussing ideas related to the social reform perspective during the PD.

When the data is presented by measuring time spent on ideas related to each teaching perspective, there are surprising revelations. Even though the transmission perspective appeared frequently throughout the PD, as measured by frequency counts, the instructional team spent the least amount of time discussing ideas related to this teaching perspective. Additionally, the apprenticeship perspective, which was only coded at the beginning of the LS cycle, comprised about 30% of the total coded meeting time. The nurturing perspective, which was only the third most coded perspective, comprised 20% of the total meeting time. Though, and as expected, the instructional team spent a large amount of time communicating ideas related to the developmental perspective, which aligns with the frequent appearance of the developmental perspective code. The case study I present in this chapter will shed further insight into these discussions.

It is important to note that the data accounted for in this analysis comprises only 30% of the total meeting time. The other 70% of meeting time was dedicated to other activities such as providing an overview of logistical lab instructions, watching teaching recordings, explaining content, discussing classroom management, and other miscellaneous topics.

Table 4.3: Percentage of time spent verbally communicating ideas related to each teaching perspective

	Transmission	**Apprenticeship**	**Developmental**	**Nurturing**	**Social Reform**
Time spent discussing ideas (minutes)	15:00	27:13	30:14	18:13	0:00
% total out of time coded	16.5%	30.0%	33.4%	20.1%	0.0%

Recognizing that teaching perspectives were coded at a lower frequency in the second LS, I also wanted to explore how time spent on each teaching perspective may have shifted over repeated LS cycles. Figure 4.1 depicts a 100% stacked column representing the amount of time the instructional team spent discussing ideas related to a particular teaching perspective during LS cycle 1 (Weeks 2-3) and LS cycle 2 (Weeks 4-5). More time was spent discussing ideas related to the transmission perspective in cycle 1 when compared to the time spent in cycle 2. The amount of time spent discussing ideas related to the developmental perspective increased from cycle 1 to cycle 2. There was no time spent discussing ideas related to the apprenticeship perspective in cycle 2.

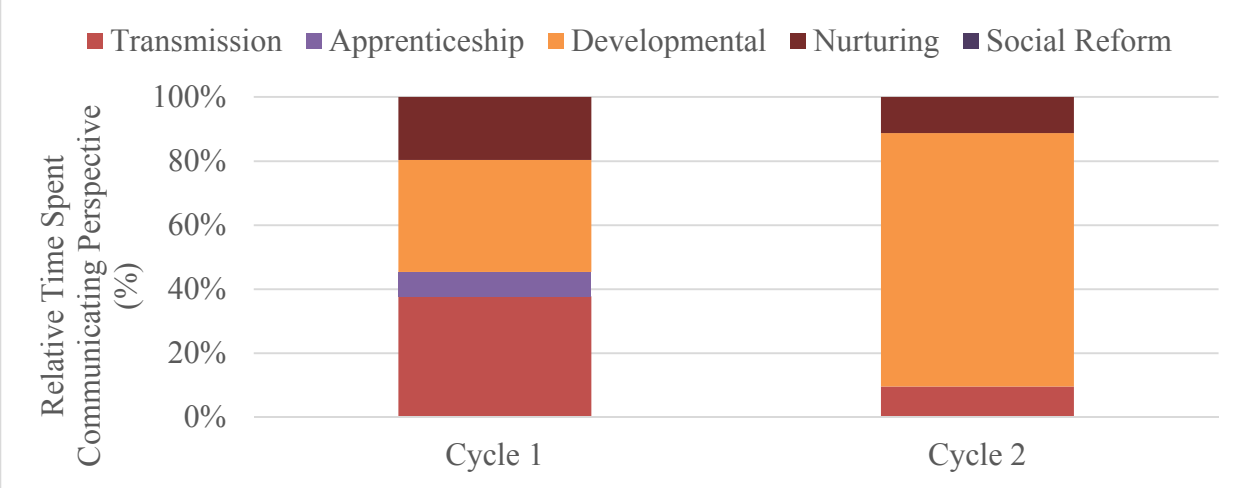

Figure 4.1: Comparison of time spent communicating ideas related to each teaching perspective sorted by LS cycle

Ethnographic Case Study

In the following section, I chronologically describe the events of each meeting with Course 2 instructional team. I detail the sequence of activities, the prompts I posed, discussion ideas, and teaching perspectives being communicated through these ideas.

Meeting 1

Prof. Martin led the first half of the meeting and began by asking the GTAs how their first lab sections went. The GTAs reported that students had a lot of questions regarding the course organization and expectations. Then, Prof. Martin spent time orienting everyone to the Canvas (learning management system) course page, highlighting the different modules, assignments, discussion boards, and resources provided. Prof. Martin also oriented the GTAs to the Hayden-McNeil online lab simulator, which students were supposed to use for their labs each week, as well as the GTA Google folder which contained course assignments and the rubric for grading the course assignments.

After, Prof. Martin spent time discussing the pre-assignment, the lab, and the lab report for the upcoming week, which was focused on introducing students to volumetric equipment. In this discussion, Prof. Martin and two GTAs who previously taught this course shared common calculation mistakes that students are prone to doing during this lab and shared tips on how to address these mistakes. This first part of the meeting ended with Prof. Martin encouraging the GTAs to share any feedback or student reactions to the different lab components because the virtual learning environment and online lab simulator that they were navigating was the first time the department is using the format and program.

Establishing Norms and Expectations

Prof. Martin handed over the meeting to me. I began by orienting the instructional team to our shared Google Folder which contained our meeting slides, running brainstorm document, and the weekly reflection form. I also described the basic model of LS and then transitioned into the first activity, which was establishing group norms and expectations. To introduce the activity I said:

> An important element that has really drawn me to this PD model is that teaching no longer becomes something that's individualistic, but it really becomes a collective effort. (Course 2, Meeting 1, July 9)

The activity invited each member of the instructional team to create a slide within our shared Google Slides deck where they could drop in images, quotes, or words that represent their expectations for participating in this PD and for working as a team. The instructional team worked on this activity for five minutes, and then I invited each member of the team to share their slide. I discussed my slide first in order to make a comfortable environment. While discussing my slide, I emphasized how I expect us to share our pieces of knowledge about teaching and about students in order to build a shared knowledge. I also expressed the importance for everyone to share their experiences because experiential knowledge is valid knowledge in LS. The last point I made was about respect and how I want to honor and respect each member of the instructional team as an instructor by promoting horizontal learning, meaning that I do not have all the answers about teaching, but I am learning alongside everyone.

The next person to share their slide was Margaret, a GTA, who emphasized the expectations of communicating honestly and taking risks. Margaret described risks as "really important to actually evolving a course because you can work together to keep something the same, but that's different than working together to improve something" (Course 2, Meeting 1, July 9). Margaret then called out the other three GTAs by name and highlighted how they all have different backgrounds so she is excited that they can all come together in this space.

Maia was the next GTA to share her slide and all the images and words she placed was related to collaboration because "the most valuable resources that all teachers have is each other" (Course 2, Meeting 1, July 9). Maia encouraged members of the instructional team to be willing to share their knowledge, experiences, and perspectives.

Following the same line of thinking, Narcissa, who was the next GTA to share her slide, also expected members of the instructional team to share their experiences, including "what's worked, what hasn't worked, and how students responded to various techniques" (Course 2, Meeting 1, July 9). Narcissa discussed how she felt it was important for the instructional team to be honest and transparent with one another about any issues that arose with students or the labs so that they could learn from one another. Narcissa ended by saying that Prof. Martin has always served as a resource for her when any issues arise.

Alex was the last GTA to share her slide. Alex began by describing her favorite physicist and how he is an inspiration to her as a teacher because he was always responsive to people who wrote him letters. Alex also described her own schooling experiences and how her experiences motivate the kind of teacher she wants to be. She introduced a nurturing perspective into the meeting by highlighting the importance of the instructor:

> When students don't connect with their professors or they're disrespected by them, it can really affect the way [students] see certain topics. And chemistry is one of those topics that I hear so many people say, "Oh, I had such a bad experience in chemistry." But it's like the best subject ever (…) Part of my goal is to show people that even though they think they're not good at [chemistry], it's actually a really cool thing to learn about. (Course 2, Meeting 1, July 9)

In this excerpt, Alex is showing a commitment to supporting and encouraging students so that they can have good experiences in chemistry. Lastly, Alex expressed excitement for participating in this PD experience because she believed she could improve her teaching by learning alongside the other members of the instructional team, which would be in contrast to her prior GTA experiences where her previous instructional teams did not put students at the center of their teaching. Prof. Martin elaborated on Alex's nurturing perspective ideas and emphasized how she values the GTAs because they all work as a team to support students:

> I truly believe in building you guys up so you can build my students up, and I can build them up as well. And that way, we don't have them fall. It can be hard at times, and stressful, I totally understand that. You know, student's aren't listening or they're not paying attention, but there's always an underlying factor to that and that's what I really want to explore. (Course 2, Meeting 1, July 9)

In this excerpt, Prof. Martin encouraged her GTAs to consider the affective components of teaching and explore what may be impacting student motivation and attitudes.

Prof. Martin continued on to describe her slide and introduced a transmission perspective by emphasizing the importance of working with students to ensure they are understanding the material correctly:

> You'll notice I have a discussion board every week for students and I give them points for it. This is where I can see where students are not understanding the material and for me to hop in immediately and go, "Hey, let me explain this problem. You guys aren't reading this question correctly. Let me break this down for you." And I did. This allows me to quickly address the problem. (Course 2, Meeting 1, July 9)

In this excerpt, Prof. Martin is expressing a commitment to efficiently and accurately ensuring that students gain mastery of content. Prof. Martin ends her slide description by re-introducing a nurturing perspective and emphasizing how the instructional team should work to understand student circumstances and support students through challenges.

After all members of the instructional team shared their slides, I re-iterated the common themes throughout the slides, including collaboration, sharing of knowledge, and communication. I also emphasized how this PD was not about critiquing everyone's practice, but it is an opportunity for us to learn more about students so that we could be better equipped to help them learn the material. I originally planned to have a second activity that displayed two different list of team norms from existing literature and would invite the instructional team to modify, add, or remove certain items. Due to the limited time after the slide sharing activity, I decided to skip the second activity and transition into developing research themes.

Developing Research Themes

I began this next part of the meeting by introducing the purpose of a research theme in LS and illustrating a student development theme and an equity theme with examples. After, I presented the instructional team's departmental welcome message that was displayed on their website. I chose to display the department's welcome message because it was most similar to a public departmental mission and vision, which I did not have access to. As the instructional team read the welcome message, I prompted them to write down some words or phrases that were salient to them in the running brainstorm document. After individual reading and reflection time, I opened it up for group discussion.

Margaret began the discussion by pointing out that the welcome message emphasized the various number of degrees the department offers and the different research opportunities that students can participate in in order to prepare students for employment. Margaret also pointed out that the word "teaching" was only mentioned once. Margaret felt like the message was written towards an audience who were the "uppers ups, you know, the people that care about the money that's coming in. It didn't feel like it was meant for the students." (Course 2, Meeting 1, July 9). Narcissa chimed in agreeing with the points that Margaret made, applauding the department on their commitment to preparing students for employment but expressing disappointment because there were parts that felt "pretty empty." (Course 2, Meeting 1, July 9) Maia joined the discussion agreeing with Margaret and Narcissa, but also added on to the conversation saying that she "missed the equity, diversity, and inclusion ideology" (Course 2, Meeting 1, July 9) within the welcome message as there was no substantial commitment to these issues. Alex mentioned how the welcome message emphasized many of the department's past

achievements but feels like "it doesn't talk about how they're continuing to evolve." (Course 2, Meeting 1, July 9)

After all the GTA shared their thoughts, I redirected the discussion towards the formulation of the student development and equity themes. Narcissa began by introducing ideas related to the apprenticeship perspective:

> I want my students to develop into independent thinking scientists that are able to think critically and logically and learn how to use their resources to find information, instead of just, you know, crying when they don't get everything given to them on a silver platter because these are skills that, no matter what field you're going into, you need to have. (Course 2, Meeting 1, July 9)

In this excerpt, Narcissa communicates a commitment to enculturating her students into the ways of working in chemistry, including how to think and use resources. Margaret agrees with what Narcissa says but then shifts the conversation and introduces ideas related to the nurturing perspective:

> I agree. I also just have like a more nebulous addition. I just want them to have like, open-mindedness. Alex said earlier, like a lot of people don't like chemistry because they have a bad experience with it or whatever and then they hate the subject. I don't know how exactly to do this but give [students] a chance to decide whether or not they like [chemistry]. Let them have the independent thinking like Narcissa said—not trying to convert everyone to chemistry but letting them have the chance to decide whether or not they like it. (Course 2, Meeting 1, July 9)

In this except, Margaret showed a commitment to creating a climate of trust and encouragement for students. Margaret is also showed consideration for individual student growth as chemists, not solely just their achievement in chemistry knowledge and skill. Alex continued with the nurturing perspective emphasizing how she felt we, as instructors, need to empower students and help them develop resiliency.

After this discussion, I encouraged the instructional team to write out their student development and equity themes so that we could document our progress and have it for reference during the remaining weeks. For the student development theme, Narcissa wrote down:

> I want my students to become independent scientists that are able to think critically and be able to use their resources to find the information they need instead of complaining when everything isn't give to them on a silver platter. (Course 2, Brainstorm document)

Alex challenged the group to use less "negative language" and edit the word "complain." Margaret suggested using the word "expecting" and elaborated on how some students expect to be given directions without saying anything or asking questions. Alex then recalled an instance during the first week of lab when a student asked if Alex would post a video giving directions for the online lab simulator, to which Alex said that the syllabus and Canvas page already lays out that information. This led to a group discussion on how Course 2 is often one of students' first college courses and students are still trying to navigate time and course load. Ideas related to the apprenticeship perspective appeared several times in this conversation as Prof. Martin encouraged all the GTAs to project the Canvas Course 2 calendar for their lab sections and go through the important dates listed so that students could add important exam and assignment due dates to their personal calendar.

Furthermore, Margaret added on to this conversation by sharing challenges she had with students not coming to lab prepared. To address Margaret's concerns, Prof. Martin and Narcissa described the importance they place on letting students know lab is a place for questions and, as instructors, it is their responsibility to teach them how to study and interact with course materials. This conversation, which lasted approximately 20 minutes, conveyed the apprenticeship perspective because the instructional team committed themselves to socializing the students into the practices of higher education.

By the end of the meeting, the instructional team developed the following two research themes:

> *Student development theme:* Students should be able to be independent scientists who can think critically and leverage their resources to find the information they need instead of expecting everything to be given to them on a silver platter.
>
> *Equity theme:* Students should be able to build the confidence to stay resilient when faced with challenging problems, and students will be able to access the material, especially disciplinary terminology. (Course 2, Brainstorm document)

Meeting 1 Summary

Alex's nurturing perspective, which was first introduced when establishing norms and expectations, highlighted affective components of teaching that were considered and brought back into the meeting by other members of the instructional team, including Margaret and Prof. Martin. It may be important to consider if Alex's presence on the LS team was crucial in the appearance of the nurturing perspective because she was the main contributor of this perspective during meetings.

The apprenticeship perspective was the most frequent perspective that appeared in this meeting and took up the greatest amount of discussion time; this can be attributed to the nature and purpose of a LS research theme. A LS research theme is a long-term goal that instructors want their students to work towards and achieve (Stepanek et al., 2007). As chemistry instructors, it is natural for the instructional team to want their students to be able to learn how to engage in lab settings, which requires critical thinking and knowledge on how to use surrounding resources. The instructional team also recognized that they are instructors to students who are new to the college setting and committed to also wanting their students to gain the skills necessary to succeed in a college classroom.

Finally, while a social reform perspective did not appear during this meeting (or at all throughout the LS process), I recognized a missed opportunity to introduce this perspective. During the analysis of the department's welcome message, Maia commented on how there was a lack of attention to valuing diversity, equity, and inclusion. Maia's idea was not sustained and did not re-appear throughout the meeting's conversation; however, as facilitator, I could have encouraged deeper exploration around this topic (de Vries & Uffen, 2021) and prompted the instructional team to consider the role of diversity, equity, and inclusion in the department and in the classroom. Having such conversations may have resulted in a different equity theme, such as having a focus on empowering students and contributing to diversity in the chemistry field.

Meeting 2

Lab coordinator, Prof. Johnson, joined Meeting 2. Prof. Martin began the meeting by introducing the lab for the week, which was focused on learning about limiting reagents. Limiting reagents was the focal labs for Cycle 1. Prof. Martin answered some logistical questions about student attendance, then proceeded to walk through the steps in the lab and through the questions in the lab manual, detailing what she expects students to do in the lab and how to answer the questions. As Prof. Martin was explaining the calculations needed to answer the lab manual questions, Margaret unmuted and said "stupid question" in order to gain Prof. Martin's attention and ask for a clarification. Prof. Martin responded by saying "No such thing as a stupid question and you know that" (Course 2, Meeting 2, July 16) and then proceeded to answer Margaret's question. Prof. Martin finished walking the GTAs through the lab procedures and manual and handed over the meeting to me.

Cycle 1 Study Phase

I began the LS meeting by reviewing our team norms and revisiting the research themes that we developed in Meeting 1. I reviewed the purpose of our research themes, projected the two themes on Zoom for the group, and invited members of the team to make any edits or suggestions; though, everyone agreed on the themes and no changes were made. I also presented the four phases of LS to the team and marked how we were going to engage in the study and plan phase in today's meeting for the limiting reagents lab.

I started the study phase by restating the purpose of the study phase and letting the instructional team know that, in this phase, we will take on the student perspective to try and understand how students view, think about, and respond to the material. Then, I projected three terms to the group—alternative conception, partial understanding, and misconception. I prompted members of the instructional team to define each phrase and think about how the three terms are connected. Narcissa began by introducing a developmental perspective in order to draw connections between the three terms:

> If [students] have alternative conceptions about what topics they're learning, they don't match what the main point we are trying to drive home is. That probably indicates they have a partial understanding of what they're doing. And then I feel like misconceptions stem from having alternative conceptions of what they're working on. (Course 2, Meeting 2, July 16)

Narcissa also expressed how as instructors, we should recognize these different conceptions and understandings that students may have about the topic. Alex and Margaret agreed with Narcissa and carried on with a developmental perspective by committing to uncovering students' partial understandings and different conceptions. Margaret adds:

> Partial understandings aren't inherently good and bad. Like half of it you understand, half of it you don't. (Course 2, Meeting 2, July 16)

Then, Maia challenged her peers and said:

> I think it's more like, incorrect. Like an incorrect way of thinking about the labs or general conceptions. (Course 2, Meeting 2, July 16)

After Maia, I prompted the instructional team to define what they mean by incorrect or wrong. Margaret was the first to chime in and introduced a transmission perspective:

> [Students] are missing a key piece of information that helps them understand the story. Or they just frankly don't understand something. Like they don't know that a negative sign means energy released or they think it means gain, and those things are just a factual mistake. But some are missing a piece of knowledge and they don't know what they're missing so that makes it hard for them to understand. (Course 2, Meeting 2, July 16)

Margaret continues to show a commitment to ensuring that students know necessary details or pieces of information. Narcissa adds on to the conversation and maintains the transmission perspective by emphasizing her role as the instructor is to deliver the factual knowledge:

> Some [students] actually are understanding the point behind what we're doing and like, when I explain things and I tell them why things are the way they are, they get it the first time, but the majority still don't. (Course 2, Meeting 2, July 16)

I returned to the idea that the study phase brings us closer to understanding how students think about a topic, what conceptions or partial understandings they may hold, and how we, as instructors, can bring students' knowledge to the scientifically agreed upon ideas and definitions. Alex introduced a nurturing perspective into the conversation and discussed how there may be many barriers students experience that inhibit their agency to ask questions and clarify their ideas:

> One of the barriers are just getting students to communicate because a lot of students are afraid to tell you that they don't understand, or they don't want to seem like an idiot. And so, sometimes what I do is I just tell people, 'You know, ask questions, no matter what. Don't be afraid to speak up.' And if they do ask a question, even if it's the simplest question, I really make sure not to shame them over it… (Course 2, Meeting 2, July 16)

Margaret, Prof. Johnson, and Prof. Martin maintain the nurturing perspective and reiterate the importance of creating a learning environment that fosters questions. Prof. Martin brings up the

scenario that happened in the first part of the meeting when Margaret said, "stupid question" and Prof. Martin reassured her that there were no stupid questions. Narcissa chimed in and offered her approach as to how she tries to create such an environment:

> From day one, I tell them, "Look. You're here to learn. I'm here as a resource for you. Ask me whatever you want. I don't care if I have to repeat it (…) I guarantee whatever question you're thinking—that you think is a bad question—everyone else is thinking it too. No one wants to speak up." (Course 2, Meeting 2, July 16)

Prof. Martin then orients the GTAs to the Canvas discussion board as a resource for the GTAs to learn what types of questions students may have. Prof. Johnson followed-up and asked if the discussion board leads to students cheating, but Prof. Martin suggested that the discussion board actually promotes collaboration as some students will answer other students' questions.

After the conversation about discussion boards, Prof. Johnson returned the conversation to the three terms being projected on the slide (i.e. alternative conception, partial understanding, and misconception) and offered a developmental perspective by recognizing how my approach to facilitating a conversation around these three terms is a good way to introduce chemistry terminology to students:

> You should make sure that everybody understands every term that you're using. Because sometimes even now [students are asking], "what is this?" but you're trying to focus on something else. So asking for some similarities or differences with these terms, that's what I'm learning and that's really important. (Course 2, Meeting 2, July 16)

Narcissa, Alex, and Margaret agreed with Prof Johnson and maintained the developmental perspective as they offered tips on how they have approached introducing chemistry terminology with their students. I chimed in by describing how the discussion directly related to our equity theme and ensures that terminology is accessible for students. These ideas portray a developmental perspective because the instructional team paid close attention to the ways in which they were introducing and using scientific jargon. The team is also recognizing the

responsibility they have with adjusting their teaching and responding to students' current level of understanding.

Then, I transitioned our discussion towards the study phase for the limiting reagents lab. I prompted members of the instructional team to reflect on the time when they were students first learning about limiting reagents or on their first time teaching limiting reagents. I asked them to identify any concepts that were difficult to grasp and think about reasons why they thought these concepts were difficult to grasp. In response to the prompt, Narcissa offered a developmental perspective by emphasizing the importance of relating limiting reagents to baking:

> I break it down and just talk about when you bake a cake—talk about the different ingredients and how if you have too much of "X," you don't end up making a cake. I also push the students and ask if someone else has an idea of how they want to explain it. (Course 2, Meeting 2, July 16)

Then, I steered the conversation and challenged the instructional team to think about what if students did not understand limiting reagents right away, even after using the baking analogy. The instructional team remained silent after I posed the question so I went to the next slide, where I projected the three skills related to professional noticing of student thinking: (a) attending to students' strategies, (b) interpreting students' understandings, and (c) deciding how to respond on the basis of students' understandings (Jacobs et al., 2010). I introduced the body of research on teacher noticing and defined each skill. Then, I presented the following problem:

The following reaction is used to obtain small amounts of chlorine gas in the laboratory:

$$MnO_2(s) + 4HCl\,(g) \rightarrow MnCl_2\,(s) + Cl_2(g) + 2H_2O(l)$$

If 28.0 g of MnO_2 are allowed to react with 42.0 g of HCl, what is the limiting reactant? I had the instructional team individually read the problem and think about how they might solve it. Then, after the team solved the problem, I asked them to think about a student who gave an incorrect answer and answered manganese dioxide as the limiting reagent. I prompted the

instructional team to make inferences about that student's thinking. Alex suggested that maybe that student is not understanding the math calculations that are necessary for solving the problem. Margaret offered her method of solving limiting reagents problems, which is to start with each of the reagents, use the reagent amounts to calculate for one of the products, and compare which reagent produces a bigger amount of product. Narcissa added to the conversation by saying she teaches limiting reagents using the same method Margaret does.

In this moment, I found it difficult to orient the instructional team towards thinking about wrong answers so I offered up my line of reasoning. I mentioned how one strategy a student might be employing is comparing the number of moles of each reagent. Thus, a student might see that the equation includes one mole of MnO_2 and four moles of HCl on the reagent side and come to the conclusion that the limiting reagent must be MnO_2. I then cited research on how this calculation strategy has been found to be a common mistake that students do when solving limiting reagent problems (BouJaoude & Barakat, 2000). I opened the discussion up to the group for any thoughts or other possible strategies that students might take when solving this problem, but I was met with silence. For a second time, I invited the instructional team to recall their previous experiences with teaching and learning limiting reagents as these experiences might give insight into student thinking, but the team remained silent. Then, I transitioned the discussion into the plan phase.

Cycle 1 Plan Phase

Recognizing the limited time I had left in the meeting, I transitioned into the plan phase and let the instructional team know that the focus of planning will be on the introduction to the lab, as requested by Prof. Martin. I presented our research themes and prompted the instructional team to think about how we can purposefully structure the introduction to the limiting reagents

lab so that we can work towards our research themes. I oriented the instructional team to the brainstorm document and asked them to brainstorm ideas activities or questions they might pose to students in order to introduce the limiting reagents lab.

After approximately 5 minutes of individual think time, Prof. Martin chimed in to offer the suggestion of using a YouTube clip of a Father of the Bride movie segment where a character is seen complaining about how hot dogs are sold in 8-packs but hot dog buns are sold in 12-packs (https://www.youtube.com/watch?v=oYIHLUxzRr8). Prof. Martin described how the video offers students a real life example of limiting reagents.

When looking at the brainstorm document, three out of four of the GTAs wrote down procedural steps on how they would approach the lab. For example, Narcissa wrote the following:

1. Introduce what [limiting reagents (LR)] means and why it is important/relevant
2. Balance the reaction and explain why it needs to be balanced
3. Walk through the calculation steps to determine LR
4. Walk through calculation steps to determine theoretical yield of product
5. Walk through calculation steps to determine XS reagent
6. Walk through calculation steps to determine % yield
7. Walk through how I double check my answers & make sure they make sense
8. Ask if they have questions in between each step
9. Ask if the products can be LR's and why they can't be LR's

(Course 2, Brainstorm document)

The steps that Narcissa wrote down portray a transmission perspective because she has committed to presenting the step-by-step procedure students need in order to answer limiting reagent problems. Also in the brainstorm document, Alex wrote the following:

> I do like the idea of the 8 hotdogs and package of 6 buns. Buns are the LR. This is so simple and easy to understand.
> Rather than comparing the two masses of reagents I like to show how many moles of reagents create how many moles of products. Moles are like legos.
>
> (Course 2, Brainstorm document)

In this note, Alex is showing a commitment to connecting scientific concepts to real-world examples, suggesting that she is trying to use students' prior knowledge to build complex understandings (i.e. developmental perspective).

When I opened up the discussion for GTAs to share what they wrote down in the brainstorm document, Narcissa maintained her transmission perspective and conveyed her commitment to delivering the calculation procedures to the students. Then, Prof. Martin commented on Alex's ideas from the brainstorm document and offered a developmental perspective which emphasized the importance of using simple concepts, like legos, and common language before introducing the scientific terminology, so that students can build upon their existing knowledge.

I pushed the group to make a decision about the first activity they would do with their students and the group decided that in the first two minutes of the lab, all the GTAs will play the Father of the Bride video that Prof. Martin suggested. Narcissa, who agreed to also playing the video then expressed resistance to modifying her method of teaching limiting reagents, saying:

> I just really like the format of how I teach this stuff because it allows [students] to understand how to calculate all the various details that they could be asked for. (Course 2, Meeting 2, July 16)

Alex followed up to Narcissa's comment and asked if Narcissa could demonstrate the calculation steps she would show her students. Narcissa proceeded to describe how she would define each term, what she would write on the board, and how to compare the molar values. Margaret added onto Narcissa's explanation and proceeded to explain the calculation steps using the chemical equation and problem I posed earlier. In their explanations, Margaret and Narcissa both demonstrated a commitment to breaking down each calculation procedure into reasonable steps

so that there is no ambiguity about what follows, which suggests operation from a transmission perspective.

Then, Prof. Martin challenged Margaret and Narcissa and asked how they would approach teaching if a student came to them and was using a different method of solving limiting reagents problems. Margaret said she would just tell her students from the beginning to not look up answers online because those methods may not work or lead to incorrect answers. Alex challenged Margaret and implied that there may be different correct methods for solving the same type of problem. In this comment, Alex also introduced a nurturing perspective:

> If you found a way that works for you and it gets the right answer, then do it. We might learn differently and say, I'm trying to teach you one way, but I may not be teaching it the way that's going to be best for you. I try to encourage [students] to seek other resources if they're not understanding what I'm saying. (Course 2, Meeting 2, July 16)

In this excerpt, Alex is showing a commitment to strengthening students' self-efficacy by trusting that students know how they learn best. Prof. Martin added on to Alex's point and mentioned how limiting reagent problems can also be solved using an Initial, Change, Equilibrium (ICE) table. Prof. Martin introduced a developmental perspective by emphasizing how the different methods to solving limiting reagent problems places the responsibility on instructors to consider what students know and what students are comfortable with and then work with this knowledge to find a method that works best for them.

I lost connection and got dropped from the Zoom call for about five minutes, but within those five minutes, Prof. Martin took on an apprenticeship perspective and took the time to discuss that, in addition to considering students' prior knowledge, the GTAs should also invest in reviewing the course expectations of participation in lab. Prof. Martin, Alex, and Narcissa had a conversation about how they feel like they have a responsibility to not only make the

expectations explicit to students, but to also explain why these skills and practices are relevant for the rest of their college experience and their careers in science. For example, Narcissa said:

> I give them the rules and I tell them like, these are the reasons things are the way they are. You're here to learn time management, how to analyze data—you're not going to be a chemist necessarily, but you are going to be in the scientific field, how to read instructions. You need to learn this here and that's why these things matter, and it's going to benefit you in the future. (Course 2, Meeting 2, July 16)

In this excerpt, Narcissa is showing a commitment to enculturating her students into the norms and practices of higher education and of being a scientist.

To bring the conversation back to planning the lab after I returned on the Zoom call, I oriented everyone back to the brainstorm document where I had written the first step of the lesson as showing the Father of the Bride video. I asked the instructional team what they wanted as their next step. Using a developmental perspective, Alex suggested that we start with doing problems using the hot dogs and hot dog buns example and then relate this example to a chemical equation:

> We can use something like we have eight hot dogs and six hot dog buns. This equals six completed hot dogs and two naked hot dogs leftover. Then we can present a simple chemical equation and show that this chemical represents the hot dog buns and this chemical represents the hot dogs. (Course 2, Meeting 2, July 16)

Narcissa suggested using a chemical equation where the reagents and products are not a 1:1 ratio because, in her experience, students make mistakes on their calculations using this assumption (i.e. developmental perspective); using a more complex chemical equation where the ratio of reagents to products are not 1:1 allows for Narcissa to demonstrate all possible steps and calculations that students need to know. Margaret suggested building sandwiches as the real-life example rather than using hot dogs and hot dog buns because this allows for both the GTAs and students to play around with different ratios, since two pieces of bread are needed for one

sandwich and there could be different requirements for fillings (i.e. two pieces of cheese, one slice of ham, etc.). When Alex asked Narcissa to choose a problem so that they could all do the same problem with their students, Narcissa expressed resistance saying that the GTAs should all do different problems so that students can watch all the different lab recordings and get experience with different problems. Recognizing that I had run out of time and that the team was struggling with building a shared lesson plan, I wrapped up the discussion by inviting the GTAs to use problems of their choice, but focus on demonstrating the calculations by using the build-a-sandwich example. Margaret volunteered to have her teaching recording be viewed in Meeting 3.

Meeting 2 Summary

The two perspectives that were most frequently used in Meeting 2 were the developmental and transmission perspectives. Members of the instructional team were offering ideas related to the developmental perspective in the study phase, which can be attributed to the discussion surrounding Prof. Johnson's comment on how I introduced the words "alternative conception," "partial understanding," and "misconception." From Prof. Johnson's remark, the instructional team recognized how their teaching needs to be responsive to students' prior knowledge and current understanding of scientific topics. The instructional team also identified that in order for them to help students achieve a complex way of understanding, they, as instructors, need to first build the simple blocks (i.e. defining terminology) that will eventually lead to a more sophisticated way of understanding.

I think the transmission perspective was salient in the plan phase because the prior teaching experiences that GTAs had with teaching limiting reagents was very much focused on delivering step-by-step procedures on how to solve problems. The consecutive appearance of transmission ideas were broken by Alex's nurturing perspective, which challenged the

instructional team to consider different ways to solving problems. I think that the developmental perspective appeared in the plan phase as a result of the discussions from the study phase. In response to Alex's comment, members of the instructional team transitioned to considering the knowledge and experiences that students come into the lab with and how this knowledge and experiences can be scaffolded and connected to limiting reagents.

The apprenticeship perspective that appeared during the plan phase was a result of Prof. Martin's contribution to the discussion. Her commitment to enculturating students into higher education was also carried on by Alex and Narcissa, suggesting that the presence of certain people and the perspectives they bring impact how the instructional team talk about their role in teaching.

Meeting 3

Lab coordinator, Prof. Johnson, also attended meeting 3 with the Course 2 instructional team. Alex had to leave early from the meeting. Prof. Martin began the meeting by reviewing the calorimetry lab that the GTAs would be doing with their students in the upcoming week. Prof. Martin also oriented the GTAs towards resources on the Canvas page and encouraged the GTAs to walk through these resources with their students because she also posted tutorials on how to use Microsoft Excel to create the graphs necessary for the lab report.

Cycle 1 Teach Phase

Prof. Martin handed over the meeting to me and I began by first showing them the four phases of a LS cycle. I highlighted how in our last meeting, we thought about ways students might think about limiting reagents (i.e. study phase), and then we planned for ways we could engage the students in our introduction of the concept (i.e. plan phase). I stated that the purpose of the next phase (i.e. teach phase) was to watch someone teaching what we planned to their

students and give us the opportunity to refine our own conjectures about teaching, learning, student thinking, and instructional design. Then, I oriented the group towards the brainstorm document, where I pasted in the observation guide found in Figure 4.2:

Approximate time of video	**Learning Task**	**Point to note regarding student development theme**	**Point to note regarding equity theme**	**Student thinking**	**Additional observer notes**	**Wonderings**
	What is the instructor doing? What are the students doing?	What evidence do we note that can confirm or disconfirm that students are thinking critically? Leveraging their resources?	What evidence do we note that provides evidence that students are building their confidence? That the material is accessible for students?	What does this clip tell us about student thinking?		What other questions do you have?

Figure 4.2: Observation guide for teaching phase

I formulated this observation guide based on the instructional team's research themes, which is why the questions in the guide prompt the instructional team to identify specific pieces of evidence that related to thinking critically, leveraging resources, building confidence, and accessibility of material. After presenting the guide in the brainstorm document, I displayed the team's research themes and provided reasons for why I added in these prompts. I allowed members of the instructional team to review their research themes and familiarize themselves with the observation guide.

Then, I invited Margaret to share any feelings she had or any caveats that she felt like she wanted us to know before viewing her clip. Margaret shared that she felt like the students were engaged in the activity and appeared to understand how to solve the problems. After Margaret shared, I played the 12-minute teaching recording for the team.

In the recording, Margaret began by introducing the students to key terminology and clarifying that students may see both the term "reagent" and "reactant" in the textbook, lab manual, or exam problems, but these terms both mean the same thing and can be used interchangeably. Margaret defines what reagents are and explains how reagents will always be located on the left side of the equation to make products, which are on the right side of the equation. Margaret prepares to show her students the Father of the Bride video and prompts her students to think about what things in the video are the reagents and what things in the video are the products. Margaret plays the video. After the video ends, Margaret asks the class what the problem in the video was. One student says that there is an excess of buns. Margaret ties this to the concept of limiting reagents.

In the recording, Margaret begins the next section of her introduction to the lab by setting up the sandwich example. She poses to the class that she wants to make a sandwich that consists of two pieces of bread and one piece of cheese. Margaret draws seven pieces of bread on the board and three pieces of cheese, and then asks the students to write down in chat how many sandwiches they can make. Many students answer "3" in the chat, to which Margaret says they are correct. Margaret then defines the example using chemistry terms by letting students know that three sandwiches is the theoretical yield because, given the ingredients, we can theoretically make three sandwiches. Margaret continues her explanation and tells students that the limiting reagent can be found when the theoretical yields for each reagent is determined. Margaret changes her example and removes one piece of cheese so that the board displays seven pieces of bread and two pieces of cheese. When asked the students what the theoretical yield is, students in the chat write "2." Margaret then explains how the seven pieces of bread would ideally yield three sandwiches, but the two pieces of cheese would yield at most two sandwiches, making the

cheese the limiting reagent. Margaret continues on with the sandwich example, introducing the additional ingredient of salami, and playing around with the starting number of each ingredient. Students respond to her questions through chat. The teaching recording is clipped when Maggie transitions into the lab.

Cycle 1 Reflect Phase

After viewing the teaching recording, the brainstorm document is not filled with many observations. I give three minutes of individual time and invite the instructional team to write down their thoughts on the teaching recording, but even after this working time, the instructional team has very minimal written down. Some of the comments include "students participated in the discussion" and "students were getting the correct answers." Recognizing that I may not get any additional comments, I started the debrief.

Following traditional LS debrief procedures, I asked Margaret to share first and discuss her experiences and feelings when teaching the lesson. Margaret recognized that she made a mistake because she called the ingredient "ham" when it was "salami" initially, but the instructional team members assured her that it did not harm the lesson. Margaret did not share anything after, so I opened up the discussion to other members of the instructional team by asking what they found positive about Margaret's teaching.

Narcissa volunteered to start the conversation and introduced a nurturing perspective by commenting on how Margaret's humor and casual language appeared to foster a genuine relationship with the students and seemed to motivate them to engage with the sandwich activity. Narcissa also noted that she observed the students were "more confident" in their answers towards the end of the teaching clip because students were responding faster with the answer to each question. Alex and Sasha continued with the nurturing perspective and both commented on

how Margaret's enthusiasm seemed to appeal to students' emotions because she was making learning fun and motivating students to participate.

After members of the instructional team shared their initial thoughts, I invited the team to identify pieces of evidence within the video that would help us determine if we accomplished our research themes. Margaret began by talking about how in the video, there was an instance where one student unmuted to answer Margaret's question, but the student incorrectly identified the limiting reagent. Margaret hesitated, restated the amount of ingredients they had to make a sandwich, and then asked the student to think about the question some more. Margaret commented on how the chat was flooded with the correct answer after that which indicated to her that students were understanding the concept. In this dialogue, Margaret is showing a commitment to ensuring that students master the content and get the correct answer, conveying a transmission perspective.

Prof. Martin and Prof. Johnson both commented on how it seemed like more students were contributing answers in the chat as Margaret continued to do example problems, suggesting that more students felt more confident in the material since they were offering answers. When I prompted the instructional team to think about other pieces of evidence that bring insight into how students are thinking about limiting reagents, members of the instructional team kept referring to student answers in the chat. Prof. Martin also noted how the answers offered in the chat were correct, suggesting that students were not only engaged but were understanding the material.

Recognizing that the instructional design of this lesson did not offer much insight into the process of student thinking as the instructional team was only able to view final answers contributed by students, I transitioned the discussion into asking the other GTAs about their

experience with teaching the lesson. Narcissa began the discussion by saying that she did not follow the lesson and instead approached the lab as she would have done in other semesters (i.e. walking through the step-by-step procedures to calculate the theoretical yields of each reagent); Narcissa took on a transmission perspective by emphasizing that with her method, her students were providing correct answers to the questions she was posing.

Realizing that I was limited on time, I transitioned the discussion to focus on broad takeaways that members of the instructional team can implement for their future lessons. Narcissa, taking a nurturing perspective, emphasized how Margaret's teaching clip has motivated her to try non-chemistry examples because she wants to better motivate students to engage in the material and make it a fun learning experience:

> I think what I'm going to take from it is trying to incorporate more fun. Like non-chemistry examples before diving into the chemistry. I'm so used to starting with simpler problems that evolve into complicated problems. I only have so much time and can only really cover like two to three problems max, so I tend to just go straight to the material (…) but it would be nice to do what Margaret did. (Course 2, Meeting 3, July 23)

Narcissa added on to her comment and offered a developmental perspective when reasoning why these real-world example are useful:

> Incorporating real world examples is helpful. It's relatable. The students never think the material applies to them. (Course 2, Meeting 3, July 23)

The rest of the instructional team agreed with Narcissa and maintained the developmental perspective by highlighting how the real-world examples enables them, as instructors, to activate the prior knowledge students have already because of their daily life experiences; activating prior knowledge readied the students to connect their life experiences with the chemistry content.

Prof. Johnson ends the conversation by offering a nurturing perspective and highlighting how Margaret's method of using the sandwich example at the beginning is strengthening

students' self-efficacy because it enabled students to build confidence and engage in a stripped-down version of the material before adding any intimidating scientific terminology. I recognized that my time for the meeting was over and ended the session by thanking Margaret for her willingness to show her teaching clip and thanking the instructional team for the productive discussion.

Meeting 3 Summary

The two most prominent perspectives that appeared in this meeting were the nurturing and transmission perspectives. Ideas that conveyed a nurturing perspective were brought about as a result of watching Margaret's enthusiasm when teaching and the connection she was establishing with her students through her humor, casual language, and fun activities. By watching Margaret teach, the instructional team really latched on to thinking about ways in which they, as instructors, could foster the same motivation that Margaret instills in her students.

Ideas that conveyed a transmission perspective were most salient when discussing the evidence of student learning and evidence that our research themes were accomplished. Members of the instructional team were drawing on evidence that support a commitment to mastery of the content (i.e. correct answers, how quickly students were answer).

The developmental perspective also appeared during the reflect phase, and it was most closely associated when discussing the importance of integrating real-world examples into the introduction of labs. The instructional team were highlighting how real-world examples enables students to activate their prior knowledge, making them more willing and ready to build a more complex and sophisticated understanding of scientific concepts.

Meeting 4

Prof. Martin began the meeting by discussing an incident involving Course 2 students committing a violation of academic integrity. Prof. Martin reminded her GTAs to encourage their students to follow the institution's rules and conduct in order to uphold academic integrity or they will be reported to the Students Rights and Services Center. Prof. Martin also let the GTAs know the steps she took when speaking to students and the reasoning behind the decisions she made when handling this incident. After discussing the incident, Prof. Martin proceeded to review the lab procedures and expectations for the upcoming lab on freezing point depression, which is the focal lab for LS cycle 2. Prof. Martin ended her segment by reminding the GTAs of the deadline to submit lab grades to ensure they meet the Registrar's timeline.

Cycle 2 Study Phase

Prof. Martin handed the meeting over to me and I projected the four phases of the LS cycle to orient the instructional team that we will be starting a new cycle in today's meeting. I also recapped the takeaways from our prior cycle and discussed how we (a) studied ways that students might have thought about limiting reagents, (b) planned an introduction to the lab by using real-world examples that students have encountered in their daily lives, (c) watched Margaret teach the lesson and engage her students in a captivating activity, and (d) reflected on ways we can improve our teaching, which will inform our next LS cycle.

In a weekly reflection that was submitted after Meeting 3, one GTA expressed concern over how to engage in the three features of teacher noticing given the constraints of lab time. More specifically, in the reflection form, the GTA wrote:

> I'm still wondering how to incorporate Nicole's 2.1 bullet point #1 (attending to students' strategies) into our [lab] classes. We do not have an opportunity to check [students'] work during class, especially under time constraints. (Course 2, Meeting 3 Reflection, July 23)

I took this opportunity to start a discussion about how to approach wrong answers. Margaret chimed in by saying that if students are answering incorrectly, she'll ask her students to reconsider their answers without telling them if its right or wrong. Maia agreed with Margaret and said she will ask the students if they have other guesses. Alex offered a developmental perspective about what she would want to ideally do:

> If I'm trying to get [students] to understand an equation, I might leave them with leading questions. I might say, 'Okay, if this is the energy of whatever, then what is this?' (…) Or I try to rephrase the question. (Course 2, Meeting 4, July 30)

In this excerpt, Alex is showing a commitment towards students building on their own knowledge. Alex implies that she wants to guide the students in a certain direction but ultimately give them the opportunity to define aspects of an equation or scientific construct and strengthen the links between these different aspects. However, after she offer this developmental perspective, Alex admits that she usually takes on a transmission perspective when teaching:

> If it's in class, especially with time constraints, I tend to just kind of tell them the answer. (Course 2, Meeting 4, July 30)

Then, Narcissa and Margaret pondered on ways to gain better insight into understanding how students come to an incorrect answer. Narcissa said:

> Maybe ask them to explain how they got their answer, and by doing so, they realize where their mistake was made. And [I] would explain that to them, explain the correct answer and why it's right and ask if they have questions. (Course 2, Meeting 4, July 30)

I continued the discussion by suggesting that GTAs may also already have an idea about why students make an incorrect answer. For example, in the study phase from cycle 1, we anticipated common misconceptions or calculation mistakes that students might have when determining limiting reagents. Then, I replayed a 30-second segment of Margaret's teaching clip from Meeting 3 where Margaret posed and answered limiting reagents problems using the

sandwich example. Margaret displayed seven pieces of bread and five pieces of cheese on the board and changed the requirement of a sandwich, where a sandwich now required two pieces of cheese instead of one. Margaret asked the students, "How many sandwiches can be made?" One student unmuted and responded, "three sandwiches," which is an incorrect answer. Upon hearing the student, Margaret stated, "We changed it, we now need *two* pieces of cheese per sandwich" and paused until the student corrected themselves and said, "two sandwiches" (i.e. the correct answer).

I paused the video after this segment and opened up the discussion by asking what the instructional team noticed about Margaret's approach to the incorrect answer. Maia commented on the chat that Margaret was nice to the student and did not shame the student for not getting the right answer. Other GTAs agreed with Maia's comment. I prompted the GTAs to consider how Margaret responded to the student's incorrect answer. After some silence, Alex spoke up and offered a developmental perspective, highlighting how Margaret seemed to almost know right away that the student did not take into account the number of cheese slices per sandwich, which was why Margaret chose to repeat the requirements for a sandwich. Alex attended to the ways in which Margaret identified a "sticky point" (Pratt & Smulders, 2016, p. 164) and worked towards helping the student build a more sophisticated understanding of the factors in the calculation process. This allowed me to step into the discussion and highlight how as GTAs, while it may be unconscious, there are moments where we might already be attending to students' strategies because of our prior experiences learning the material or previous experiences with teaching the topic to students. Margaret added on by saying that her response felt "kind of second nature" and she was already anticipating that common mistake that students

make, which may have led her to use that example in the first place. I emphasized that the study phase in LS essentially enables us to think about and anticipate student thinking more explicitly.

Then, I transitioned the group into the study phase for the freezing point depression lab. I projected the research themes to remind the instructional team can be reminded of the goals they had for their students. I began the discussion by asking the GTAs to consider the methods they will use to engage students in the lab. I purposefully approached the study phase differently from cycle 1 with guidance from my reflective partners. I recognized the difficulty I had in cycle 1 with trying to push the instructional team to think about student thinking but noticed that during the cycle 1 reflect phase, the instructional team fixated on the methods Margaret used to engage students. My reflective partners suggested that perhaps the instructional team's focus on student engagement was an artifact from the virtual teaching setting, where instructors have anecdotally shared their struggles with engaging students in Zoom learning. My reflective partners also suggested that the instructional team may not often be positioned to focus on student thinking and are therefore susceptible to conflating student thinking with student engagement; however, discussing student engagement may be an entry point into considering student thinking. For these reasons, I decided to open the study phase discussion by asking GTAs to talk about how they might want to engage their students in the lab.

Margaret opened up the discussion by saying that she surveyed her students on the first day of lab and asked their preference, which was to remain in the main room as a whole class when answering the lab report questions so that everyone received the same material. Narcissa shared that her students preferred being in breakout rooms to answer their lab report questions and she would pop into the rooms to check on the students regularly. Alex and Maia agreed with using Narcissa's method. After everyone shared their method of engagement, I prompted the

instructional team to think about ways we could leverage students' engagement to learn more about how they think about a certain topic. Margaret generally said that questions asked by the students shed light on what may be confusing for them. Alex expanded on this and said that when students are in breakout rooms, they are more likely to ask each other questions first and, if other members of the group are also confused, they would call onAlex to clarify. Alex then shared that when this occurred, it gave her insight into what other students may find confusing, so she will hop into the other breakout rooms to cover the same material with the other groups. However, when asked about how they answer student questions, the GTAs maintained a transmission perspective because they said they usually just re-teach content to clarify.

Then, I used this point to transition the discussion into thinking more specifically about how students might think about the freezing point depression lab. I asked the instructional team to reflect on their previous teaching and learning experiences with this lab and identify different ways students thought about freezing point depression. Prof. Martin mentioned that students often mix up the solution and the solvent when solving a problem. Additionally, Margaret stated that in her experience, students do not have trouble grasping the concept of a freezing point depression, rather they have trouble with experimental parts when performing the lab (e.g. where to put the salt when setting up the experiment apparatus); Margaret added that because the labs were a simulator for this particular term, the GTAs would not have to worry about those mistakes this term. This may be a reason why there was an observed decrease in the amount of coded segments in cycle 2 when compared to cycle 1.

When there was silence for a few moments, Margaret spoke up again and stated that she has sometimes seen students get confused about the different parts of the freezing point depression formula (i.e., $\Delta T_f = i \times K_f \times molality$). I asked Margaret to clarify what she

meant when she talked about students being confused with the different parts of the freezing point depression formula, to which she and Prof. Martin offered an explanation that referenced the smaller blocks of knowledge students needed in order to understand. Margaret said that students should first understand that the equation is going to produce a number that represents a change in temperature (i.e., ΔT_f). Prof. Martin said students need to also understand what molality is, and Margaret added on that the students need to make sure that their molality has the unit of solvent. Prof. Martin added that students must also distinguish between an electrolyte and a non-electrolyte in order to determine the van 't Hoff factor in the equation (i.e., *i*). The breakdown that Margaret and Prof. Martin performed for the group conveyed a developmental perspective because they were laying out the necessary pieces of knowledge students first need before building these ideas into a more complex concept. After Prof. Martin and Margaret offered the breakdown of the freezing point depression equation, the instructional team spent time clarifying with one another the scientific definitions and ways to calculate each component of the equation.

Cycle 2 Plan Phase

As facilitator, I did not have to make any formal transition into the plan phase because the conversation organically followed in that direction. As the instructional team spent time reviewing the definitions of key terminology and the variables needed to perform the calculations, they also formulated examples that GTAs could use to best demonstrate each definition and calculation. For example, when discussing how to introduce the topic of electrolyte vs. non-electrolyte to students, Alex suggested to introduce students to non-electrolytes by using the sugar molecule (i.e., $C_6H_{12}O_6$). Because the compound is comprised of

non-metal and is a molecular compound, sugar will not dissociate into ions, which is the definition of a non-electrolyte.

Additionally, Alex asked the group what everyday examples could relate to the freezing point depression. Margaret offered the example of putting salt on the road during winter and described how the salt will lower the freezing point of water making it so that the ice will not re-freeze after melting.

When I invited the instructional team to write out a lesson outline in the brainstorm document so that everyone could use the same examples when describing the different scientific terms and concepts, I experienced resistance from the group as they mentioned they already discussed the examples as team together earlier in their discussion. I also tried to bring back the student engagement discussion by asking if there was one method of student engagement that all the GTAs could try so that we could compare how students might respond to it; I was met with resistance from the team saying that they wanted to continue using their methods because it reflected students' preferences. Rather than forcing the instructional team to write out a plan, I recapped the basic outline of how the introduction of the lab might start off with a real-world example, such as putting salt on an icy road, and then transition into a breakdown of the different scientific terminology and concepts needed to solve for freezing point depression through the use of examples. Narcissa agreed to using her teaching recording for our next meeting.

Meeting 4 Summary

Similar to other phases and meetings, the developmental and transmission perspective were again prominent in Meeting 4. In the study phase, when discussing approaches to wrong answers, the GTAs tended to describe a transmission approach by correcting students and demonstrating the correct way to think about or calculate the answer to a problem. However, the

conversation slowly shifted towards how GTAs might approach wrong answers if there were no time constraints and they discussed ideal strategies (e.g. rephrasing questions, asking leading questions, asking students to show their thought or problem-solving process) which align with a developmental perspective because they are committing to breaking down and sequencing the problem solving process to promote student understanding.

In the plan phase, the developmental perspective was prominent because the instructional team focused on anatomizing the complex concept of freezing point depression into individual concepts (e.g. van 't Hoff factor, electrolyte vs. non-electrolyte, molality) to ensure that they could provide scaffolds for students so that students could achieve a more complex understanding of the formula. Additionally, the instructional team also focused on identifying examples that students would know in order to describe and define the individual concepts (e.g. introducing the sugar molecule as a non-electrolyte), showing a commitment to building off students' prior knowledge.

Meeting 5

Meeting 5 marked the last meeting with the instructional team. Prof. Martin was present but did not participate in this meeting. Because there were no more lab sections after this meeting, there was no need to review course content, so we transitioned straight into the LS portion of the meeting.

Cycle 2 Teach Phase

Before viewing Narcissa's teaching clip, I projected the four phases of LS cycle to illustrate to the team how we are in the latter half of our second LS cycle and how in our previous meeting, we focused on really identifying the necessary knowledge students need in order to understand freezing point depression. Additionally, I presented the team's research

themes again to remind them of the goals we set for ourselves and our students. Then, I oriented the instructional team to the brainstorm document with the observation guide pasted in so that they could use it as a guide while watching Narcissa's teaching clip.

Narcissa's teaching clip was approximately 13 minutes and in this clip, she was reviewing the different components of the freezing point depression formula (i.e., $\Delta T_f = i \times K_f \times molality$) with the students in a manner similar to what was being discussed in the planning phase of Meeting 4. For example, when teaching the students about the van 't Hoff factor, Narcissa purposefully chose two different molecules (i.e. NaCl and CH_4) which would demonstrate the differences between an electrolyte and a non-electrolyte. She also included a diagram of a beaker filled with water and the dissociation of Na^+ and Cl^- to illustrate what she meant by "dissociate." One student in the chat asked how you would know if something were to dissociate in water. To answer this question, Narcissa first asked if students were familiar with "Lewis dot structures." Students in the chat answered yes, so Narcissa proceeded to draw the Lewis dot structures of NaCl and CH_4 to demonstrate the differences in polarity between the two molecules.

Cycle 2 Reflect Phase

After viewing the teaching clip, I noticed that the observation guide in the brainstorm document was not filled with any notes; recalling how the instructional team had not been keen on writing things throughout the LS process, I just proceeded into the debrief and discussion. Following traditional LS debrief procedures, I invited Narcissa to first describe her experiences and emotions when teaching. Narcissa described how when she initially prepared for the introduction in lab, she was writing down the definitions of key terminology and the procedures needed to calculate freezing point depression. This preparation approach conveyed a

transmission perspective because Narcissa was showing a commitment to ensuring students obtained the mastery of the content. However, Narcissa described how during the lab period, she felt compelled to illustrate and clarify the terminology using examples:

> I didn't think of like—I didn't plan on giving these examples initially. I wanted to do one example using an electrolyte and one example using a non-electrolyte to help clarify how to determine the van 't Hoff factor. (Course 2, Meeting 5, August 6)

After Narcissa shared her experiences of teaching the lesson, I opened the discussion up to the other members of the research team by asking for evidence from the video that demonstrates whether or not we accomplished our research themes. Alex was the first to share and she noted how Narcissa's picture showing the dissociation of molecules in water is a strategy that can make the scientific terminology more accessible for students. Margaret expanded on Alex's point by mentioning how Narcissa's visual depiction of dissociation was her way of highlighting a typical mistake that students often make in this lab, meaning that students will be more likely to have a solid foundation when solving other problems. In this dialogue, Margaret offered a developmental perspective because she was paying attention to how Narcissa anticipated students' common mistakes and usould extra time to facilitate understanding so that students can achieve a more complex understanding of the concept.

Margaret also described how, in the clip, Narcissa praised and thanked students for their engagement in the lesson. Narcissa extended to say that she purposefully also used student names when they answered because she "wanted to get them stoked" (Course 2, Meeting 5, August 6) and referred to Margaret's teaching in cycle 1. The points that Margaret and Narcissa mention from the clip appealed to the nurturing perspective because they were attending to the ways Narcissa tried to motivate students in their learning.

Narcissa then mentioned how in her teaching, she was able to leverage students' prior knowledge of the Lewis dot structure to show students how to determine if a molecule is an electrolyte or a non-electrolyte. In this dialogue, Narcissa demonstrated a developmental perspective because she was activating students' prior knowledge in order to explain a more complex topic.

Then, I transitioned the discussion so that the instructional team could think about what teaching ideas or strategies from this LS cycle they could use in the future. Margaret offered a developmental perspective and said that this LS cycle really helped her see the importance of defining complex topics by using the scientific concepts that students already know. Margaret noted that in Narcissa's teaching, Narcissa was able to spotlight the scientific concept students already knew (i.e. Lewis dot structure) but then connect it back to the larger picture, which is something that Margaret wants to improve and practice on.

Alex attended to the nurturing aspects of Narcissa's teaching and said that her biggest takeaway was how Narcissa engaged with her students by asking them questions, waiting for an answer, praising them, and calling them by her name. Alex said that in the past few terms as a TA, her students did not interact with her or answer her questions; thus, Alex was going to try the student engagement strategies that she observed Narcissa implementing.

Meeting 5 Summary

The most prominent teaching perspectives in Meeting 5 were the developmental and nurturing perspective. There was one instance of the transmission perspective, which was relayed by Narcissa when she described that her initial approach to preparing for lab was to outline the definitions and calculation procedures related to freezing point depression. However, Narcissa described how as she taught the lesson, she decided to really break down and illustrate the

different components of the freezing point depression formula using content that students already knew. Both Margaret and Narcissa offered a developmental perspective when reflecting on the teaching recording because they were attending to the ways in which Narcissa activated students' prior knowledge and worked on building up students' understanding of freezing point depression. Alex maintained a nurturing perspective and highlighted the ways in which Narcissa interacted and engaged her students in the lesson and how this essentially motivated her students to learn the content.

Summary of RQ1 Findings

Transmission Perspective

The frequent presence of the transmission perspective, which focuses on ensuring students master content knowledge, was not surprising. In fact, the transmission perspective has previously been reported at higher frequencies with math and science teachers compared to language arts teachers (Collins et al., 2003). The association between the transmission perspective and math and science disciplines is hypothesized to be attributed to the nature of such disciplines, as the content is well-defined and there is a clear "right" and "wrong" answer (Collins et al., 2003; Rotidi et al., 2017). In addition, there have also been empirical studies that report STEM GTAs often hold onto a transmission perspective (Gardner & Jones, 2011; Goertzen et al., 2010). In this study, the transmission perspective appeared quite frequent in the first LS cycle, especially when planning the lesson. When asked to plan the lesson, many of the GTAs opted to essentially create a procedural check list that relayed the correct way to do a calculation, which portrayed a commitment to effectively disseminating content. There was even resistance to straying from this method by some GTAs because they insisted the procedures were all students needed to master the content. The transmission perspective also appeared when

GTAs were tasked with thinking about attending to incorrect answers. The GTAs recognized how they would simply correct incorrect answers and attributed such an approach to the limited time constraints they faced in lab section. It seemed that the source of the transmission perspective in LS discussions were coming from the GTAs themselves, rather than to a specific LS phase.

Apprenticeship Perspective

The apprenticeship perspective, which really focuses on enculturating students into a specific community, was mostly observed during the development of a research theme. In this phase, it was apparent that the instructional team wanted their students to be able to think and act like chemists, which is a natural goal for all instructors to have. Additionally, the team also recognized that their course is one that students take early on in their college career, leading the team to also want their students to learn good study strategies, organizational skills, and time management to succeed in college. I suspect that the development of a research theme naturally brings about an apprenticeship perspective because it asks teachers to envision the idealized qualities and traits they want in their students (Takahashi & McDougal, 2016), and most likely, these qualities and traits will be those that are valued within their discipline or context.

Developmental Perspective

After analysis of the data, I am led to believe that the LS structure encourages the developmental perspective. Recall, the developmental perspective conveys a commitment to helping students develop more complex ways of reasoning or thinking about a topic. The model of LS prompts teachers to think about content from a student's perspective. In other words, the activities and discussions in LS asks teachers to anticipate student thinking and plan ways to respond to their thinking (Lewis et al., 2009). Engaging in such activities and discussions

essentially requires teachers to breakdown a concept and think about ways they can scaffold such knowledge for their students.

Additionally, I think the modified LS model used in my study particularly emphasized the developmental perspective because the lessons were focused on connecting content to real-world examples. Having this focus really centers the developmental perspective because the instructional team is fundamentally identifying what is most likely going to be students' prior knowledge and experiences and then purposefully planning ways to connect this prior knowledge and experience to the content.

Nurturing Perspective

I believe the presence of the nurturing perspective is unique in this case study because it was almost always contributed by one individual—Alex. If the perspective was not directly contributed by Alex, someone in the group was expanding on her current idea or previous ideas back into the conversation. Alex was the first to bring it up in Meeting 1, and after viewing the teaching recordings, Alex always commented on the affective components of teaching. It was unclear to me if the nurturing perspective was attributed to Alex's presence or specific LS phases.

The nurturing perspective appeared quite frequently in Meeting 1. While I think the presence of the nurturing perspective during the establishment of norms was solely because of Alex's contributions, the presence of the nurturing perspective during the development of the research theme could be because of the nature of the activity. As described above in the apprenticeship perspective section, the development of research themes requires teachers to identify idealized qualities of students. I think that the inclusion of an equity theme in this LS model prompted the instructional team to think about the student experience within the course

and within the chemistry discipline. Recognizing that chemistry is often intimidating for students, the team was prompted to consider the affective components of learning, including the establishment of self-concept, persistence, and motivation. In doing so, the nurturing perspective may have been a natural outlook to have.

I also think that the debrief of the lesson in the reflect phase may facilitate a nurturing perspective. In the debrief of lessons, the team often commented on how students responded to an activity or an interaction with the GTA (i.e. students feeling comfortable with Margaret's use of casual language, students feeling excited when Narcissa calls them by name, etc.). In this way, the team tended to measure student thinking and student engagement through their imposed understanding of student attitudes and emotions. The attendance to these attitudes and emotions may be a reason why the nurturing phase was present.

Social Reform Perspective

While the social reform perspective was not observed in this LS, I hypothesize that further probing when developing a research theme could prompt such ideas. The social reform perspective emphasizes the goal of teaching beyond the learning environment. Therefore, discussion about research themes and what certain student qualities and traits mean beyond the classroom and beyond college may prompt teachers to think about what their teaching means in a broader societal context. In the case study, I point out how there was a missed opportunity to further elaborate on the importance of diversity, equity, and inclusion in chemistry and in the department. I envision that if I pursued this comment with the instructional team, they may have discussed how their teaching might be important in retaining diverse students in STEM, who will ultimately go on to diversify the STEM workforce and STEM fields.

Chapter 5: CHAT Lens on LS

In this chapter, I present the findings for RQ2: *What are the communities, division of labor, and norms that impact the ways instructional teams engage in LS?* Leveraging the third-generation CHAT framework (Engeström, 1999; 2001), I coded the LS meeting discourse, artifacts, and post-study interviews to determine the communities, division of labor, and norms that were influenced the ideas and approaches to teaching that the instructional teams were discussed. From my analysis of the data, the instructional teams were navigated ideas and values from two systems: the LS system and the department system. As the researcher, I made the assumption that both systems potentially have a shared object to support undergraduate student learning. I made this assumption for the LS system, as this is the goal of LS. I also made this assumption for the departmental system based on the department's welcome message and the institution's mission and vision.

From my analysis of the data, I propose that LS offers participating instructional team members, most especially the GTAs, the opportunity to (a) confront tensions created between their values and the values being communicated by the department and (b) co-construct and operate from new system dynamics. More specifically, the data suggest that the implicit departmental norms and dynamics, with regard to teaching, do not align with the values and beliefs of the instructional team, prompting the team to explicitly co-construct new norms and dynamics for one another. Figure 5.1 depicts the two systems along with each system's communities, division of labor, and norms. In this chapter, I present the communities, division of labor, and norms for each system and provide evidence from the data to illustrate the tensions that emerge within the instructional team members from being part of both systems.

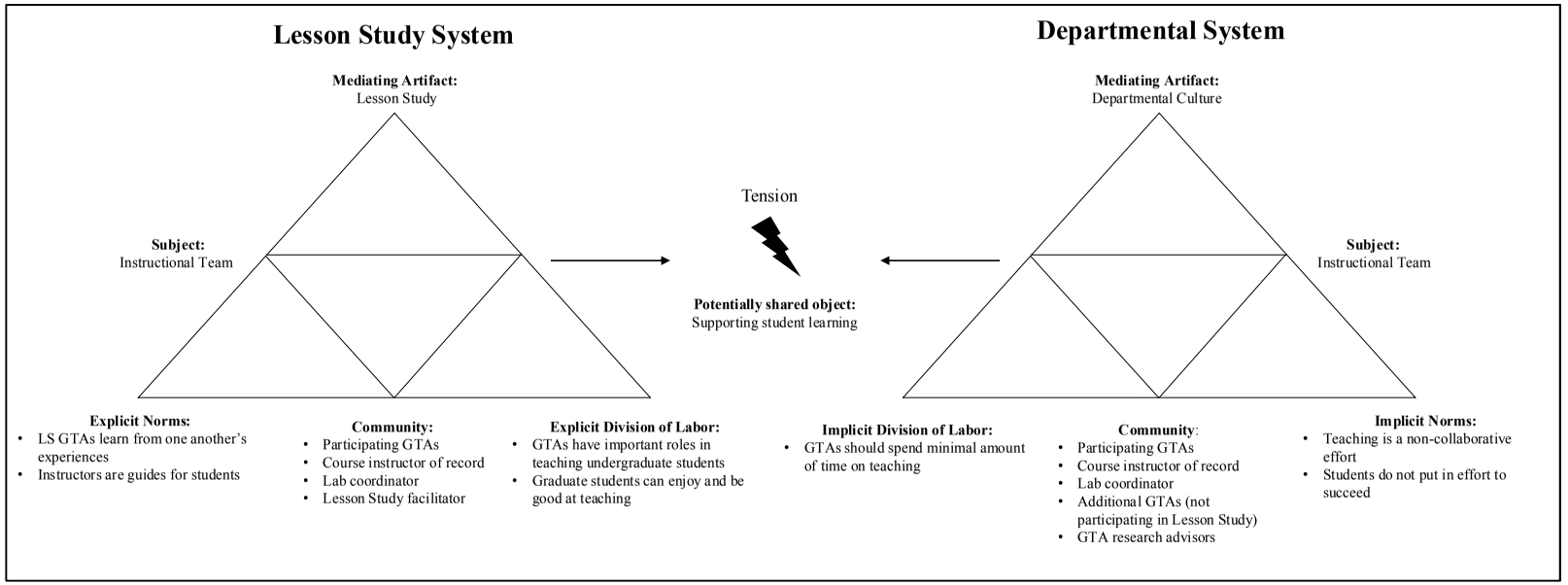

Figure 5.1: Tension between LS system and departmental system

Community

The community within an activity system represents the people who come together to form a system. By recognizing the community as a factor within the system, we are considering the range of different viewpoints, values, beliefs, interests, and histories that these individuals bring in. Dependent on the division of labor of the community, the viewpoints, values, and histories of authority figures within the system are more likely to shape the system.

For the purposes of this study, the subject for each system is the LS instructional teams. The community for the LS system included the participating GTAs, the course instructor of record (Prof. Martin), the lab coordinator (Prof. Johnson), and me as the LS facilitator. The community for the departmental system included the participating GTAs, the course instructor of record (Prof. Martin), the lab coordinator (Prof. Johnson), the GTAs that were not participating in LS but were peers with our study GTAs, and the research advisors to our GTAs. The different viewpoints, values, and histories of each system's community members shape how labor is divided and what norms are upheld, as detailed next.

Division of Labor

The division of labor within an activity system represents the distribution of different positions and roles in order to achieve the object. Articulation of who does what, when, and why sheds insight into the values and the power structures that are being followed by the community.

Departmental System: GTAs should spend minimal amount of time on teaching

The participating GTAs revealed their department communicates that teaching undergraduate students should not be a priority for graduate students and that GTAs should spend minimal amount of time on their teaching responsibilities. This message has been explicitly communicated by the GTAs' research advisors and implicitly communicated through

the lack of opportunities that the GTAs have had to reflect upon and improve their teaching. For example, in the following excerpt, in our first LS meeting when analyzing the department's welcome message, Margaret described her appreciation for the opportunity to participate in LS because she had previously been discouraged from spending time on her responsibilities as a GTA by other research principal investigators (PIs). Prof. Martin furthered Margaret's claim and described how she has been frustrated with the department's failed commitment to the undergraduate students:

> Margaret: It's nice to be heard as teachers. I don't know, like, I really want to be a teacher and I've noticed in my time as a grad student that most of the faculty don't encourage you to spend time teaching at all, or even [spend time] thinking about it, so I appreciate this.
>
> Prof. Martin: But we're a teaching institution.
>
> Margaret: I know, but it's like, you know the PIs are always like, "Spend as little time grading as possible." "Go do it on the weekend so you don't have to think about it." "Don't make a lesson plan, you can just wing it." Like, they literally encourage us not to do that and to do research, so it's really nice to have a little time to talk about it.
>
> Prof. Martin: But yeah, you know, this is the thing. You know our department really needs to change. I mean, look at our mission statement, you guys definitely hit on that. (…) I was like, "Oh, we only care about degrees? Got it." We don't care about the growth of the student, the knowledge of our student, the growth of their STEM career, you know, them changing? (Course 2, Meeting 1, July 9)

Margaret and Prof. Martin had a similar conversation at the last LS meeting when they reflected on the instructional team's entire LS journey:

> Margaret: Apart from [Prof. Martin] and Nicole now, everyone encouraged us to spend as little time as possible on teaching, which is disappointing especially because I'm here to teach. I know that a small population of people come to grad school to teach, so it's very discouraging when you get here and everybody around you is like, "Teaching sucks," you know?

Prof. Martin: Yeah and I feel bad for those TAs because they miss out on the fundamental experience of learning how to translate our chemistry language to the general public. (Course 2, Meeting 5, August 6)

The message that GTAs do not need to focus on teaching was also communicated in the LS meetings with the Course 1 instructional team. For example, in the following dialogue, Freddie and Natia, the two GTAs for Course 1, described their prior GTA experiences and how meetings were focused on reviewing course content rather than on deepening their understanding of teaching:

Freddie: Our spring semester was more chemistry topic-oriented meetings, not teaching oriented meetings. [Referring to the LS process] This whole thing was about how to teach, how to better teach, so that's why I have not really thought about the things that, well, I think every teacher should have. This semester really helped me to start thinking about that kind of thing.

Natia: Yeah, so only focused on material that we need to cover, not exactly how to teach. So I think this was completely different from the previous Spring semester. Or semesters when I was teaching, we didn't even have meetings. (Course 1, Meeting 7, July 6)

LS System: GTAs have important roles in teaching students

Contrasting the idea that GTAs should spend minimal amount of time on teaching, throughout the LS, Prof. Martin acknowledged the GTAs for their important roles in teaching the undergraduate students. As was presented in an excerpt in Chapter 4, Prof. Martin said to the Course 2 instructional team: "I truly believe in building you guys up so you can build my students up, and I can build them up as well" (Course 2, Meeting 1, July 9). In this excerpt, Prof. Martin is expressing that the GTAs' interactions with students enables her to support her students. Prof. Martin also shared these sentiments with the Course 1 instructional team:

My expectations of working together is collaboration. I really believe in that. You guys hear from the students more than I do. How many people have come to my office hours this whole week? One. You know, that tells me that you guys are gonna give me the feedback that I need to make the course better, and discuss

> with me where the students are not understanding the material so that I can build from these experiences and this knowledge to help them grow in the course. (Course 1, Meeting 1, June 25)

The message to the GTAs from Prof. Martin in this excerpt is threefold. First, she values the presence of her GTAs because they serve as the first line of support for students. Prof. Martin acknowledged that students may not be as willing to approach her directly with questions or clarifications, but she knows that students are more likely to go to their GTAs. Second, Prof. Martin recognized that through the interactions they have with students, GTAs will have a better understanding of the student experience; in other words, the GTAs hold the knowledge of how students are doing in the class and what concepts they are still grasping. Lastly, Prof. Martin showed that she values the GTAs because she informs them know that the knowledge and feedback the GTAs bring to her ultimately informs the ways she can better support the students as well.

In another excerpt, Prof. Martin elaborated to say that the feedback she receives from the GTAs ultimately informs what parts of the course should be reconsidered and changed:

> I listen to you guys and your feedback and I take it to heart. You know, sometimes they can't change it until the following term, but I do listen and I do take in that feedback as much as I can. (Course 2, Meeting 1, July 9).

LS System: Graduate students can enjoy and be good at teaching

Another explicit organization of the community that emerged within the LS system was that graduate students can enjoy and be good at teaching. This new division of labor also contrasted the departmental message that GTAs should spend minimal amount of time on their teaching responsibilities. Throughout the LS, the GTAs themselves recognized their own abilities as instructors and their potential to better their practice. For example, Natia from the

Course 1 instructional team said the following after watching and debriefing her teaching clip with the team:

> Actually, I have to admit that I kind of enjoy teaching. I used to say that I don't really like teaching, and now I realize that when I'm explaining the material and students ask me questions, I actually answer their questions. I had a hard time—I've been hiding this for a while. (Course 1, Meeting 3, July 9)

After Natia shared this, Prof. Martin and Freddie shared their enthusiasm and reassured Natia that she is a great instructor. By viewing her own teaching clip in the teach phase and being able to talk about points of successes and areas for improvement for her teaching during the reflect phase, Natia was able to publicly share that she enjoys teaching and sees herself as an instructor.

A similar realization occurred with Narcissa from the Course 2 instructional team. Narcissa said the following excerpt on our last LS meeting when the team was reflecting on their whole LS experience. It is also important to note that in this last LS meeting, the instructional team observed and reflected on Narcissa's teaching clip for the cycle 2 teach and reflect phases; she references this experience in the excerpt.

> Pretty much before we started the summer session, especially last semester, I was—I'm not gonna lie—super fed up with teaching online. I was just getting kind of fed up with it because it felt like [the students] weren't interested in putting in any effort of actually learning. (…) When I decided to teach summer school, I decided to have a fresh outlook on the experience and I think our meetings have really helped with reinforcing that especially. I feel like these past few weeks really inspired my joy of teaching and reminded me of two things. One, that just like Margaret said, teaching is fun. I love chemistry and regardless if I like teaching or not, like I love chemistry, and it's when you have the right attitude, your students get more inspired by it too. The other thing it reminded me, especially after today's meeting, is that I am a good teacher and I can be a stronger teacher. I've been dealing with a lot of imposter syndrome and it's really tough to get through, especially when you're a Ph.D. student and everyone expects you to already know how to do everything and be perfect, especially with teaching. I was listening to the video and I was nitpicking because I'm a nutcase. I was like, 'Oh, I was talking slow' or 'I was doing this, but not that.' But through this, I remember that the reason why I talk slow is to make sure the students understand what I'm saying. The experiences here really reminded me that I do

> know enough chemistry to teach them well and teaching is fun. (Course 2, Meeting 5, August 6)

In this excerpt, Narcissa articulated how the LS process has enabled her to see that teaching is a way for her to express her enthusiasm for chemistry. Narcissa also described how when she was watching her teaching recording, she was fixated on things that she was doing that she perceived as ineffective, but the discussions with the team helped her realize how these practices may be benefiting student learning.

Norms

The norms within an activity system represent the conventions of the community and their ways of thinking and being. Norms ultimately shape how members of the system interact with one another, fulfill their designated positions, and achieve the object.

Departmental System: Teaching is a non-collaborative effort

The GTAs often described how collaborative the LS process was compared to their prior teaching experiences, revealing that the departmental system does not have structures or supports in place to foster collaboration among GTAs and faculty. Freddie and Natia from the Course 1 instructional team hinted to that in their previously presented excerpts where they discussed how past instructional team meetings mainly focused on reviewing the content that the GTAs needed to teach their students for the week.

Margaret also expressed similar sentiments when comparing the dynamic of the LS team to her past experiences of being a GTA:

> We all communicate with each other really well—nobody is like, afraid to say what they're thinking or whatever. And I think that's important in TA meetings, like this kind of communication style continues because I think it's damaging when the TAs just sit there in silence and listen to a spiel and then leave, and then they all complain together. They should have an opportunity like to talk a lot and make their teaching better. (Course 2, Meeting 5, August 6)

In this excerpt, Margaret described how complaining with one another was the extent of her interactions with other GTAs; the lack of substantive conversations that promoted reflection or improvement in their teaching. Additionally, Margaret also suggested that there was no collaboration between the course instructor and the GTAs since it seemed like the meetings would mainly consisted of the instructor reviewing the course content for the week (i.e. the "spiel").

LS System: GTAs learn from one another's experiences

In contrast to the departmental norm that teaching is a non-collaborative effort, the GTAs expressed their appreciation for the LS process and how it facilitated discussion among themselves. More specifically, the GTAs expressed how the LS process allowed them to share and receive insights into others' teaching experiences and approaches.

In the first meeting with both instructional teams, many of the GTAs wanted to establish this type of reciprocity as a norm. For example, in the following excerpt, Freddie from the Course 1 instructional team described how we, as an instructional team, were all working towards one goal, which should encourage the team to work together to achieve this goal:

> There is one point when working in a group that I thought I could do better than the group, but now I realize that, as I join professional groups, if you're working in a team, you might put in so much less effort because everything is easier when the group is working together. We are working towards the same goal and it's not just going to be forcing our students to do problem sets and watch videos, but it's towards teaching. Like teaching and group meetings with you all is not just my job, it's also sharing ideas and listening to new ideas, both feel very good and I feel like both are gonna benefit me in the future and even now. (Course 1, Meeting 1, June 25)

Similarly, when establishing norms and expectations, Narcissa from Course 2 discussed how she wanted to learn from others' experiences so that she could improve her own teaching:

> I expect that we're going to work together well as a team and share our experiences, like what's worked? What hasn't worked for us in the past with

> teaching? How have students responded to our various techniques? Especially since, for example, this is Alex's first time teaching Course 2, I think, right? Margaret and I have both taught discussion and lab but we're generally discussion TAs so we're a little rusty with teaching lab. So even if it's like negative feedback you've gotten from students about techniques you've tried with them to get them to participate, learn, etc. It's good to hear that stuff so we can avoid it in the future. (Course 2, Meeting 1, July 9)

While the GTAs set collaboration and the exchange of ideas as a norm at the beginning of the LS process, this norm was upheld throughout the academic term, and all the GTAs mentioned this as a benefit in their post-participation interviews. For example, Natia stated the following in her post-participation interview:

> Firstly, I benefited in a professional way because I learned a lot of like, a lot of new teaching strategies that I wasn't aware of before. I mean, I obviously taught in Spring Semester and back then, I started preparing slides and all, but for this semester, I feel like I developed my teaching skills because we were sharing our methods. I learned a lot on how to engage students. (…) We were really working as a team and sharing ideas and coming up with new ideas. I feel like attending these sessions, I actually felt like a team—not just under someone's supervision. I think it felt like a comfortable and safe environment. (Natia, Post-participation interview, August 18)

This norm of learning from one another was also inherently upheld through the LS structure. Natia also described how the plan phase in LS was important to her because planning the lesson allowed the team to "share ideas and combine our thoughts and experiences towards one lesson" (Natia, Post-participation interview, August 18). Additionally, other GTAs also articulated the importance of the teach phase as it enabled the GTAs to observe one another's teaching and consider how they can improve in their future practice. For example, in her post-participation interview, Maia from Course 2 said the following:

> I learned, for example, how are my colleagues' teaching styles. Or I think that I'm doing something right but maybe my teaching style is not easy to follow. So when we went through the teaching recordings, I saw what examples they used, how they explained the concepts. It was very helpful because I observed some good points—like what they're doing that I might do for next term. And I would catch what parts I'm missing during my teaching, so it was really good because by

> myself, I don't have that kind of opportunity to ask other TAs to watch how they're teaching. (Maia, Post-participation interview, August 13)

Departmental System: Students do not put in effort to succeed

Within the LS discussions, the message that undergraduate students do not put in the effort to succeed in their courses emerged. Members of both instructional teams insinuated that the faculty in the department, as well as the undergraduate students themselves, see the introductory chemistry course series as "weed out" courses. The GTAs have described that their fellow GTAs in other instructional teams hold an attitude which places blame on undergraduate students for their lack of success. For example, Alex from Course 2 mentioned her appreciation for the opportunity to participate in LS because her prior instructional team members held deficit views of undergraduate students:

> Some of my experiences with [course], not to directly bag on anyone– but I was very frustrated there. A lot of times, I would try to discuss, "Hey, let's all be on the same page and provide students with the same kind of resources," and a lot of the TA responses were like, "Oh, students are just lazy. They don't care." Well, that's not true if you just respect them. If you ignore them, yeah they're not going to care. (Course 2, Meeting 1, July 9)

Margaret from Course 2 shared similar sentiments when she implied that previous conversations with other instructors consisted only of complaining about students:

> You have to be excited, it makes a big difference. If all the teachers are commiserating together about how much they hate it, then it only enforces, like, going into the classroom with this, sort of, dry attitude of not wanting to be there. And that makes it worse. (Course 2, Meeting 5, August 6)

Members within the LS instructional teams even communicated similar messages and held their undergraduate students to low expectations; however, the LS team worked to reshape this norm and perspective, as detailed next.

LS System: Instructors are guides for students

Prof. Martin spearheaded the establishment of this system norm by stating that she does not see the introductory chemistry course series as "weed out" courses and that the intentions she has for her courses are to support students in their scientific learning and career trajectory. For example, when developing the research themes for Course 1, Natia mentioned how she wanted to move students beyond memorization of scientific formulas and facts and towards understanding the material, to which Prof. Martin responded:

> I agree, Natia. I don't want them to memorize, I want them to retain this information. I want them to understand why we are giving or approaching things in a certain way, why we're trying to have them understand these topics, because one of the biggest complaints from students is how does this relate to them? I always tell them early on that chemistry matters and is all around you. Chemistry is a study about matter, so you're understanding the world, so you definitely need it, but, you know, also making sure the students understand that this course is not to, you know, be a barrier for their degree—It's to help them understand the foundations that they're going to need to become an engineer, to become a physicist, to become a chemist, to become a biologist. Giving them a sense of, you know, this is an important course to help you grow, to validate you as a STEM student. (Course 1, Meeting 1, June 25)

Freddie followed up with Prof. Martin's idea by sharing her own experiences as an undergraduate student and describing how she wanted to serve as a resource and guide for her students:

> Yeah, I agree. I agree with everything. I was remembering myself. I was in undergrad not too long ago so I can kind of compare myself and my students now. I see how they might be struggling to understand because, when I was a freshman, I was disoriented because everything is changing so fast when you're moving from one educational institution to another one. And even though I moved to grad school now, the same happened in grad school—this confusion does not really come with experience because I was experienced. I had to undergo the same [confusion] when I started grad school. But the issue that I really see is that it's not normal to ask questions, you know. I feel like it's not really normalized that you can ask literally anything you want and [Course 1] is not for you to sit there and already have good questions to ask the TAs. I want them to be natural. These kinds of things can be achieved by having a more open relationship with your students. (Course 1, Meeting 1, June 25)

Prof. Martin shared similar sentiments in Course 2's first meeting after the instructional team analyzed the department's welcome message:

> It's important that we recognized, you know, where our flaws are, and [keep] improving for students—reminding our students that this isn't a weeding out class. I don't see this class as a weeding out class. I see it as an opportunity for students to learn and grow, and to grow up a little bit. You know, the thing is, mommy and daddy are no longer part of their education journey, it's now them, so they need to hone in on their skills, learn how to organize, learn how to time manage. That's what really makes this class hard, it's the fact that it's one of the first semester courses for our brand new freshmen. (Course 2, Meeting 1, July 9)

Prof. Martin's words really resonated with Alex prompting her to say:

> I really like what you said about this not being a weed out course because I do think that affects people's mentality going in. You know, it's like, I know so many people that go into [chemistry] and they're like, 'Oh this is so hard' and I'm like, 'It's not that it's hard, there's just a lot of work, so don't psych yourself out.' Just prepare for the volume of work, you know? (Course 2, Meeting 1, July 9)

As was described in Chapter 4, this discussion followed into the GTAs and Prof. Martin sharing different strategies on how the GTAs can enculturate students into college, which included reviewing the Canvas calendar to take note of important dates, setting study expectations, and discussing the importance of maintaining their mental health. However, within this conversation, there were instances where GTAs conveyed the assumption that students are to blame for their lack of knowledge about college courses, to which Prof. Martin and other members of the instructional team worked on offering a different perspective. For example, in the following excerpt, Margaret described her frustration with the students during her first lab session because they were not engaging in the materials that she provided them, but Prof. Martin offered Margaret a strategy that took into consideration how new the higher education setting might be for them:

> Margaret: I have this huge disconnect because I provide them with every single resource that they can humanly need to get an A in this

course. I gave them like a Google form or whatever and asked them what do they want to do for this first week. I had a sum total of zero students respond to my poll. Zero. So it was really hard for me to know, like, how or where to start. Like I don't know how to make them answer because it was there for them.

Prof. Martin: So this is how I would have started my session, "Hey guys. I sent out this Google form to kind of know where you guys are at and where I need to help you, and not one of you told me. So right now, I have no idea how I can help you, how this session could be successful so that you can get an A in this course. I'm just going to go off my background knowledge, you know, these are the common areas, but I might not be addressing something that you're truly stuck on that I should have addressed. So in the future, use this form to guide you, for us, leading the session to what you need to be addressed." (Course 2, Meeting 1, July 9)

In this example, Prof. Martin offered Margaret an alternative strategy for approaching her students which centered a learner disposition and purposefully stated why students should fill out the Google form and how it related to them.

Summary of RQ2 Findings

The use of CHAT not only enabled me to see the communities, division of labor, and norms that the instructional teams were a part of and engaging in, but it helped me articulate the tensions that team members face and the existence of two conflicting systems—the LS system and the department system. Based on my analysis of the data, I suggest that LS provided the instructional team with a space to (a) reflect on and critique the existing departmental norms and dynamics around teaching, and (b) create new norms and dynamics around teaching.

Under division of labor, the department discouraged GTAs from spending time on their teaching responsibilities. This message was conveyed by other faculty in the department, which is an attitude that subscribes to the idea of the research-teaching tradeoff (Austin, 2002; Torvi, 1994). This message was also conveyed by the lack of departmental policies or structures that allowed GTAs to engage in such PD, potentially revealing the assumption that content

knowledge is sufficient for being a teacher (Nurrenbern et al., 1999; Shannon et al., 1998; Sundberg et al., 2005). However, within the LS system there were two new perspectives that emerged to redefine and reconceive the GTA position: (a) GTAs have important roles in teaching undergraduate students, and (b) graduate students can enjoy and be good at teaching. These two new takes on the GTA role validated the comments made by members of the instructional team and ultimately support them in their teaching PD and career.

Under norms, the department conveyed the assumption that teaching is an isolated activity; an idea previously reported in the literature (Darling-Hammond & McLaughlin, 2011). More specifically, the instructional teams discussed how the extent of interactions with course instructors centered around content delivery and job responsibilities, which aligns with prior research (Hoessler & Godden, 2015; Lee et al, 2017; Nasser-Abu Alhija & Fresko, 2020). Also, the emotional support of teaching provided by peers was hinted at by team members (Myers, 1994; Staton & Darling, 1989), but it seemed to be mainly interactions centered around issues and frustrations they encountered in their teaching responsibilities. The LS system directly challenged this notion as the team members explicitly worked to establish and uphold the norm of sharing and learning from one another's experiences. The course instructor was a member of the team and participated in sharing her thoughts and experiences on teaching. The literature reports that GTAs have felt hesitant to talk about teaching with faculty because they fear being perceived as incompetent (Austin, 2002; Seymour, 2005). In the LS system, the course instructor explicitly communicated to the GTAs that she herself is still learning and improving the course and her teaching, which is why she wants to learn from them. Additionally, Prof. Martin shared her frustration with the university, which separated her from the departmental system and may have encouraged her students to open up about their teaching concerns. This mindset re-

positioned the GTAs to junior colleagues (Nyquist & Sprague, 1998) and collegial collaborators (Seymour, 2005) as both the GTAs and the course instructor worked together to improve their teaching for their students. The LS system also encouraged interactions between peers. In addition to providing emotional support, the team felt comfortable discussing their teaching strategies and ideas, which have only sparsely been described in the literature (Reeves et al., 2016; Wyse et al., 204). Learning from one another proved to be a major benefit from participating in the LS, as determined by post-participation interviews, suggesting that LS can provide can provide a formal structure for these peer exchanges to occur.

A second departmental norm that emerged from the discussion conveyed a deficit view of students and assumed that students do not put in the effort to succeed. Such attitudes and norms place the blame on students for their perceived incompetence, which can ultimately discourage students from continuing on in the course and in their pursuit of a STEM degree and career (Canning et al., 2019; Muenks et al., 2020). However, the LS system countered this narrative through the establishment of the norm that instructors should serve as guides for students. With Prof. Martin really leading this effort and challenging existing departmental norms, the instructional team began to empathize with the students and their context (i.e. new to college, unaware of effective study strategies, etc.). Prof. Martin's perspective prompted GTAs to reflect on their own experiences as an undergraduate student and realize how far they have come in their own educational journey, which served as motivation for the GTAs to take on this role as guides. Through the establishment of this norm, the instructional team were able to examine themselves as instructors and learn more about their students and their contexts, mirroring a social justice education framework (Adams & Love, 2009).

Chapter 6: LS Design Features

The purpose of my last RQ (RQ3: *What design features support the implementation of LS with higher education instructional teams?*) is to contribute ways in which the LS model should be reconsidered and modified for GTAs and the higher education setting. The goal of the design features I propose here is to provide future LS researchers and facilitators with the insights that I have gained throughout my dissertation process.

In this chapter, I introduce and illustrate four design features that I developed or want to emphasize for LS with GTAs and higher education instructional teams:

1. Undergo several cycles of LS to maximize the limited amount of meeting time, enable instructional team members to field test their teaching approaches, and promote a more nuanced understanding of teaching and learning.
2. In the study and plan phases, incorporate activities and discussion prompts that enable instructional team members to draw on their own teaching and learning experiences.
3. In the observation and debrief of the teach phase, provide scaffolds (e.g. observation guides, reflection and discussion prompts) for the instructional team to focus on student learning.
4. In the reflection phase, encourage continuous implementation and evaluation of teaching strategies to emphasize teaching as research.

Following Norwich et al. (2021), in Table 6.1, I outline the differences to certain LS elements as implemented in traditional LS and in the LS used in this dissertation. In this chapter, I will explain the origins of the design features and illustrate how they were enacted in my study or should be enacted in the future.

Table 6.1: Elements as implemented in traditional LS and in modified LS

LS Element	Traditional LS	Modified LS
LS cycle timeline	Minimum of five weeks and up to one school year for one complete LS cycle (Takahashi et al., 2005; Lewis & Takahashi, 2013; Stepanek et al., 2007)	Two weeks for one complete LS cycle
Study and planning resources	Existing curriculum, textbooks, education research, and state standards (Stepanek et al., 2007)	Prior teaching and learning experiences and facilitator-provided resources
Points of evaluation in teach phase	Planned activities that provide specific moments in the lesson which give insight into how students are thinking about the content topic (Lewis & Hurd, 2011)	Integration of specific activities from the facilitator that enable instructors to view student thought processes
Reflection	Focus on the relationship between research lesson goals, lesson activity, and student learning data (Murata & Kim-Eng Lee, 2020)	Focus on changes in instructor beliefs and practices related to teaching, learning, and students

Design Feature 1

Undergo several cycles of LS to maximize the limited amount of meeting time, enable instructional team members to field test their teaching approaches, and promote a more nuanced understanding of teaching and learning.

This first design feature was developed as an artifact of my experience recruiting for study participants. In the Winter and Spring terms of 2021, I approached six different professors teaching introductory STEM courses with only one professor (Prof. Martin) agreeing to participate. The time commitment associated with participating in the study was a concern mentioned by the five professors who declined to participate. An additional concern raised by four of the six professors was that my initially proposed LS model would require the entire academic term to complete one LS cycle (Table 6.2). As many professors already have their course schedules planned with specific weeks dedicated to certain content topics, the professors I

was trying to recruit expressed hesitancy surrounding the focus of one lesson when their instructional teams would be covering ten or more topics over the academic term.

The concern raised can be considered a "breadth versus depth" conflict, which is not new especially in science education contexts. The breadth approach is when an instructor strives to cover a wide range of concepts and topics within a specific discipline. The depth approach is when an instructor posits that a deep understanding of a few fundamental concepts is more productive (Katz & Raths, 1992; Schwartz et al., 2009). Introductory science college courses often opt for a breadth approach in order to prepare and build the basic disciplinary foundation for students who pursue more advanced science courses (Gregory et al., 2011). Thus, it is understandable that professors teaching introductory science courses also want their GTAs to have the knowledge and skills to effectively teach the wide range of content topics covered in their course. However, LS researchers argue that one LS cycle facilitate the development of teacher knowledge applicable to any content topic and subject matter. More specifically, Lewis (2009) argues that instructors who engage in LS deepen their knowledge in three different areas: (a) content and pedagogical content knowledge, (b) interpersonal relationships in teaching (i.e. working with other instructors), and (c) personal teaching dispositions and motivations. Therefore, rather than seeing the benefit of LS solely as developing a better understanding of pedagogical content knowledge, LS also offers instructors opportunities to more broadly develop their professional knowledge base for teaching (Hiebert et al., 2002).

For the reasons listed above, participating in one LS cycle is deemed sufficient and beneficial for instructors because they would be able to deeply interact with the content, study materials, team members, and student work that would encourage their PD, which is why I initially proposed only one LS cycle for my dissertation. On the other hand, as facilitator of the

LS, I also recognized and appreciated the concerns the professors shared about maximizing the PD time, which was also a point raised by members of my dissertation committee. Thus, I made the decision to implement two-week LS cycles with multiple cycles occurring over the course of the academic term. My decision to implement this structure not only acquiesced to the concerns of the professors, but can also be supported by existing research. As was described by Reeves et al. (2018), the motivation to study PD for GTAs should not be to find a one-size-fits-all approach as contextual differences between institutions, departments, courses, and instructional teams result in a wide variety of interactions and manifestations of PD outcomes. I argue that those contextual differences also exist between different labs and lessons, meaning that student responses and instructional team activities are variable between each LS cycle; therefore, engaging in multiple LS cycles will enable the instructional team to develop a more nuanced understanding of teaching and learning and identify how different factors may impact the teaching and learning process. Nicklow et al. (2007) also described the importance of giving GTAs the opportunity to "field test" their understanding of teaching and learning with their students. Dotger (2011) described a study where GTAs engaged in one cycle of LS and reported that LS enabled these GTAs to develop and refine their own theories of teaching and learning by interacting with their students in a familiar and relevant context. Thus, multiple LS cycles allows GTAs more time and opportunities to field test their theories of teaching and learning.

In addition to refining their understanding of teaching and learning, multiple LS cycles also provides GTAs with the opportunity to refine their teaching approaches. As reported by Young & Bippus (2008), teaching approaches that may sound effective in theory may not often work well in practice. Becker et al. (2017) also highlight the importance of practice-based training for supporting GTAs in using evidence-based teaching methods. Engaging in multiple

LS cycles would allow GTAs an opportunity to encounter challenges with a particular teaching strategy and, as an instructional team, they have the chance to collaboratively brainstorm ideas in order to improve that teaching strategy.

Table 6.2: Initial versus implemented LS model

Initially proposed LS model		**Implemented LS model**	
Week	**Activities**	**Week**	**Activities**
Week 1	• Identifying group norms • Developing research themes	Week 1	• Identifying group norms • Developing research themes

Week 2	• Identifying the lesson
	• Identifying lesson goals
		Week 2	LS cycle 1
			• Study phase
			  ○ Research brought in from facilitator
			  ○ Experiential knowledge from instructional team
			• Plan phase

Week 3	• Study phase pt. 1 • Researching alternative (mis)conceptions in the literature	Week 3	LS cycle 1 • Teaching/observation of lesson • Reflect phase ○ Broad takeaways for future teaching

Week 4	• Study phase pt. 2
	• Researching effective teaching strategies for topic
		Week 4	LS cycle 2
			• Study phase
			  ○ Research brought in from facilitator
			  ○ Experiential knowledge from instructional team
			  ○ Responding to incorrect answers
			• Plan phase

Week 5	• Plan phase	Week 5	LS cycle 2 • Teaching/observation of lesson • Reflect phase ○ Broad takeaways for future teaching

Week 6	• Rehearsal of the research lesson	Week 6	LS cycle 3
			• Study phase
			  ○ Research brought in from facilitator
			  ○ Experiential knowledge from instructional team
			• Plan phase

Week 7	• Teaching/observation of the lesson	Week 7	LS cycle 3 • Teaching/observation of lesson • Reflect phase ○ Broad takeaways for future teaching • Reflection on LS cycle
Week 8	• Debrief of the lesson		
Week 9	• Analysis of student work samples and observation data • Revision of lesson plan		
Week 10	• Reflection on LS cycle		

Enactment in the LS

The development of a nuanced understanding of teaching and learning can be followed through multiple iterations of LS cycles. I draw on Course 1 instructional team data to illustrate this. In the following meeting 2 excerpt, the instructional team discussed different ways to engage students in whole-class problem solving prompts:

Prof Martin: I learned how to prompt [students], so I put a really difficult problem up and I'm like, "Okay, well do you guys have any questions." And I look at their faces and I think we have questions, but let's start breaking it down.

Natia: Sometimes I challenge [my students]. I ask them, "This is how it is, so why? Why is it like that?" So they have to explain it, but it depends on what material I'm covering.

Freddie: Whenever I said, "Do you have questions?" there's like at least one question. Some students have their videos on and they're like communicating with me and like, encouraging other students. But when I give them a problem, right, and I'm telling them, "Can anyone solve it? Can anyone tell me the answer?" and it's been a minute, no one answers, it's awkward and everyone gets uncomfortable.

Prof. Martin: I think having a "call out" might help with engagement. Just start calling out students randomly and tell them you're going to do it. Like tell them you don't have to have your camera on. You can tell them, "Hey, I might be calling on you." And you do. Go, "Okay, so and so. How would I solve this?" Then wait.

Freddie: Yeah, I was trying to avoid this because maybe they don't feel comfortable answering that question, so I was trying to avoid it.

Natia: The only reason I was trying to avoid that is because I don't know how to pronounce their names.

Prof. Martin: It's okay to mispronounce names like I did with a lot of you guys. But I always tell my students, "I'm probably gonna mispronounce your name but I will eventually learn your name. Just always correct me and I will be happy to correct myself." (Course 1, Meeting 2, July 2)

In this conversation, we learn that Freddie has encountered issues with engaging students in problem-solving prompts as a whole class. Prof. Martin suggests that Freddie try calling on

student names to increase student participation. Freddie expressed hesitancy about doing this because she does not want to make her students feel uncomfortable. Natia expressed hesitancy about doing the "cold-call" strategy because she was afraid to mispronounce student names.

In Meeting 3, the instructional team observed Natia's teaching recording where she implemented the cold-calling approach. The instructional team applauded Natia's wait time for student responses and how Natia complimented how she encouraged other students in the lab to help others in the problem solving process. After Meeting 3, it appeared that the instructional team liked the cold-call approach and how it increased student participation.

The cold-call approach returned in Meeting 4 during the plan phase of LS cycle 2. Prof. Johnson asked the GTAs how they planned on engaging their students in problem solving prompts:

Freddie: I ask them to put the answer in the chat.

Natia: Yeah, sometimes one student puts the answer really fast and others take more time to do the calculations and I tell them like, "Maybe someone already put the answer, but it doesn't matter. Like your answer may be correct or you can put the same answer. It doesn't matter." And at first, there were like only four people who would put the answer, but after I said that, more people started writing in the answer. I think it is important to let them know that just because someone already put the answer—it doesn't matter—they can also write the answer and participate.

Prof. Johnson: Can you just call on particular people and, if they have problems, you can ask somebody to help them?

Prof. Martin: Actually in our last Zoom session, Natia showed us a 10-minute clip of her lab and a student got [the question] wrong, and another student helped out. So yeah, so far this has been working very well.

Prof Johnson: So, for the students who take a little bit more time or are slower and get help, do you think they feel empowered? Do they feel more confident after this? Or do they just kind of like shrink and they don't participate anymore?

Natia: I think they do like it as long as you don't like embarrass [them]. You should encourage them and say, "It's okay that you don't understand."

Freddie: And I know both of us are trying to encourage people to talk, even though it might not be a correct answer. Like I usually say, "You can have an incorrect answer. The only thing that matters that you are participating."

Prof. Johnson: That's a great thing to say because I think so many students won't be perfect all the time, that's hard to do, but if you say, "You know, we're going to make mistakes, you might not get it the first time and that's okay."

Natia: I feel like some students have anxiety with participation. Like when I was calling students out to answer questions individually the first time, one student didn't answer. And the next day, when I started calling their names again, he just left the session. So I don't know. Some people, I feel like, just have anxiety about participation or something. I don't know how to talk to him, but I feel like some students are really scared to participate and I don't know how to deal with it."

Freddie: Oh actually maybe like talk about it. Be like, "I did that calling out thing and I didn't notice any students having issues, but if you did, tell me." Then I wouldn't really ask that person again because it's something that is scaring them.

Me: One thing that I was thinking about is you would have students type their answer in chat, but ask them not to press send until you tell them all to press send. So all the answers come in at once and, as the instructor, you can strategically call on students to help you walk through the problem solving process. (Course 1, Meeting 4, July 16)

In this conversation, the instructional team members were describing the challenges with the cold-call approach. This is in contrast to the praise the instructional team was giving this approach in Meetings 2 and 3. In Meeting 4, Prof. Johnson asked a question that prompted the instructional team to think more critically about the cold-calling method from the student perspective, which invited Natia to share the experience of a student leaving because of being

cold-called. This discussion challenged Freddie and Natia to think about another method of engaging students in the lesson, to which I offered one method of using chat. It is important to note that if only one LS cycle was enacted, the team may not have been able to ponder the student perspective of the cold call approach since the first cycle focused mainly on the excitement of having students actually respond to their prompts. In addition, this also highlights the importance of having multiple perspectives. Prof. Johnson's contribution to the conversation really pushed the instructional team on the cold call approach, and by having multiple cycles, this allowed the GTAs to refine and field-test revised approaches.

The instructional team furthered their understanding and refined their approaches to student engagement in Meeting 5 when we watched Freddie's teaching clip. In the debrief of the lesson, Freddie mentioned how she tried the chat method that I suggested in the previous meeting (where students would type in their answers but not press send until they were told to do so), but described how she felt like some students were waiting until everyone pressed send to copy others' answers. As a response to this, Freddie decided to modify the chat response approach by asking students to send their answers as a private message to her instead of to the whole group chat:

> Before when I was doing this, [the students] sent me the answers in the chat and I would get exactly the same answers from all students. But now, when I told them to send me their answers, I actually got different answers. And that was good because I felt like they were actually working for themselves and not just copying from other students. (Course 1, Meeting 5, July 23)

In this second LS cycle, Freddie was able to implement an approach that was discussed in our LS meeting into her teaching and refine the approach in response to her students. In the end, Freddie had accrued multiple different approaches to engaging students in problem-solving prompts (i.e.

calling out student names; having students answer in chat all at once; having students answer in a private chat to her) and she ultimately found one that worked for her and her students at the time.

Finally, in her post-participation interview, Freddie emphasized how the iterative LS cycles were beneficial in her development as a teacher because she was able to field test different teaching approaches:

> There are like brochures you are provided when you start TAing and there is a class on different techniques or methods in teaching, but I think learning about different types of teaching methods is different from discussing and then implementing, and then discussing and implementing things—like we did, right? So like every [week], we would meet and discuss some strategy that might have worked for the future class. And then like not only discuss it but perfect it. You would say something to us, Natia would say something to us, Prof. Martin would say something and then it will accumulate and then I will use it. So learning about [an approach] then using it in a separate time frame is more difficult than thinking about it and using it next week. And then making it better, and then using it the next week. (Freddie, Post-participation interview, August 13)

In this excerpt, Freddie is really attributing the opportunity to try, refine, and re-try teaching approaches to the multiple LS cycles that she was able to engage in.

Natia also expressed similar sentiments in her post-participation interview:

> It is important to like—you will have to try something and then see how students really react. Like if you're trying to break them into breakout rooms and you want them to participate, but they don't actually participate, you will not want to do that again because it was not really effective. I think it's important to understand how students react to the strategies [you implement] in order to either improve it or keep it in your class environment. It's pretty important to really take into consideration because you don't want to repeat the same not-very-effective-strategy, right? Over and over and it doesn't work. (Natia, Post-participation interview, August 18)

As this Course 1 LS trajectory illustrates, multiple cycles of LS were beneficial for Natia and Freddie in deepening their understanding of students and improving their approaches to engaging students. While each LS cycle had a different focal lab and different content, both Natia and Freddie were able to adapt a specific teaching approach to their lab, evaluate how

students reacted to that strategy, and modify it in response to their students. Recall, Lewis (2009) suggest that LS deepens instructors' knowledge in three domains: (a) content and pedagogical content knowledge, (b) interpersonal relationships in teaching, and (c) personal teaching dispositions and motivations. One might consider that engagement in multiple, rapid LS cycles may dilute the LS process as it brings instructional teams to focus on their teaching practices rather than on student thinking around a particular content topic. While this seemed to be the case in my study, I argue that multiple, rapid LS cycles were still able to impact the instructional teams' knowledge on (a) interpersonal relationships in teaching, because they were able to work together to improve their teaching approaches; and (b) personal teaching dispositions and motivations, because they acquired newfound motivation and curiosity to improve their teaching and their students' learning experiences.

Design Feature 2

In the study and plan phases, incorporate activities and discussion prompts that enable instructional team members to draw on their own teaching and learning experiences.

Experiential knowledge is the knowledge one gains after having experienced a certain circumstance. More specifically, teacher experiential knowledge is the knowledge that one gains from any previous teaching or learning experience, including one's time as a student, novice teacher, or seasoned teacher. Teacher experiential knowledge consists of multiple facets of teaching, including different classroom routines, teaching strategies, methods to relay content, responses to student thoughts and behaviors, and ways to communicate and motivate students (Hellgren, 1988). Essentially, these prior experiences serve as the basis for teacher beliefs (Lemus-Hidalgo, 2017). Recognition of experiential knowledge as professional knowledge

suggests that knowledge can be gained *in* practice; this is in contrast to more traditional modes of PD where knowledge is gained *for* practice (Usher et al., 1997).

Acknowledging and leveraging teacher experiential knowledge enhances PD opportunities because their practices are validated by their colleagues and teacher educators, resulting in an increase in their teaching self-efficacy (Cady et al., 1998). The act of sharing experiential knowledge in a LS team is not novel and is, in fact, one of the sources of knowledge that LS team members should consider during the study phase (Lewis & Hurd, 2011; Stepanek et al., 2007). However, I find it is especially important to highlight this feature when considering LS with GTAs as GTAs are not often positioned to have teacher experiential knowledge. As was observed in my data and described in Chapter 5, graduate students are often expected to push their teaching responsibilities to the side in order to prioritize their research; thus, GTAs may have low teaching self-efficacy because they may not see their prior teaching experiences as valuable knowledge (DeChenne et al., 2015). Additionally, approaches to GTA PD are structured in a way that directly disseminates policies and certain teaching procedures (Luft et al., 2004), implying that knowledge and expertise of teaching lies in other individuals. While it is important to implement evidence-based teaching practices garnered from the large body of research that exists within the literature, I argue that GTAs do have valuable teaching and learning experiences that can and should be leveraged within LS.

Enactment in the LS

My reliance on the instructional team's experiential knowledge during the study phase is an artifact of the rapid LS cycles that I implemented. As illustrated in Table 6.2, my originally proposed LS model had a more extensive study phase prompting members of the instructional team to look into empirical research on student misconceptions and effective teaching practices

for the lesson topic. However, the change to the two-week LS cycle model demanded that, as the facilitator, I prepare for meeting sessions with already selected literature on student misconceptions to facilitate the study phase. I was concerned that this distanced the modified LS model from being a teacher-led PD, since I was being positioned as an expert disseminating information. To offset my concern, the study phase for all LS cycles began with the following prompt:

> Reflect on your time as a student first learning about [lab topic], or your first experiences with teaching [lab topic]…
> - Were there certain concepts or constructs that you identified that were difficult to grasp?
> - What were they?
> - Why do you think they were difficult to grasp?

After posing this prompt, I typically allowed for 2-3 minutes of individual think-time and then invited members of the instructional team to share their thoughts in a whole-group discussion. This line of questioning positions the GTAs as experts. The GTAs were often eager to share their experiences and Prof. Martin and Prof. Johnson usually did not contribute new ideas in this whole-group discussion; instead, Prof. Martin and Prof. Johnson would typically ask follow-up questions of the GTAs or validate something that was already shared.

In the following excerpt, I present an example from the Course 1 instructional team which illustrates the type of discussion that followed after this experiential knowledge prompt. The focal lab that the instructional team is engaged with in this cycle is the VSEPR theory lab.

> Natia: I think the one concept that was hard to understand for students, I guess, even when I was a student, is the polarity concept. Like whether molecules are polar or non-polar. Because you're talking—telling them molecules are symmetrical or something, then it's non-polar, but then they get confused. Then, if there is a lone pair it changes to getting polar, so that's one part that is hard to understand. Other parts are kind of easy, like understanding what shapes the molecules have is I think easier than to understand polarity. So I guess that's one thing that comes to my mind.

> Freddie: I completely agree with you. My first experience teaching with the spring semester, I actually had difficulties explaining that. (…) Another thing is the degrees—the angles. It's more of a technical issue but I have had students who would look up the actual [bond] angle and give me that in the lab report. (Course 1, Meeting 2, July 2)

Following this conversation, Prof. Martin agreed with both Natia and Freddie, and the instructional team went right to planning the ways in which they could address these scientific concepts. Prof. Martin described how she came up with a marshmallow, jelly bean, and toothpick activity in the lab where students can more readily visualize different bond angles. After describing that exercise, I decided to change my initial facilitator plan. After discussion about the instructional team's teaching and learning experiences with VSEPR theory, I originally wanted to spend 8-10 minutes having the instructional team dive into the education literature and find empirical studies about VSEPR theory student misconceptions themselves, but the extended discussion that the instructional team had taken up more time than I anticipated. I decided to skip that activity and go straight into presenting the four VSEPR theory misconceptions I found in the literature prior to the meeting. However, as I described in my field notes after this meeting, I was not disappointed that we did not get to that activity. One of the main reasons why I wanted the instructional team to search in the literature for empirical evidence is because I wanted the team to have ownership of the ideas and stay true to the "teacher-led" nature of LS. Yet, I realized that the experiential knowledge prompt was already enough to make the instructional team excited about addressing student ideas, as can be observed when the team went straight into planning ways to help students better understand polarity and bond angles. Natia's description of students having trouble understanding the impact of lone-pair electrons on the shape of the molecule was one of the four misconceptions that I found in the literature, which provides evidence that the

experiential knowledge of GTAs can align with the research. After presenting the additional three misconceptions, the team transitioned into the plan phase to find ways to introduce these scientific concepts in a way that students could better understand.

In another example that was described in Chapter 4, when the Course 2 instructional team was discussing how to approach incorrect answers during Meeting 4 and I replayed Margaret's teaching clip to highlight how she anticipated why a student got an incorrect answer (see description of event on p. 95). Margaret described how that move was an unconscious decision and felt "second nature" (Course 2, Meeting 4, July 30) because she recognized that as sticky point in her prior teaching and learning experiences. I think this example displays how GTAs are positioned as knowledgeable about teaching and just need opportunities that can help to develop and validate their teaching identities as well as increase their teaching self-efficacy.

As has been described in prior literature, the LS team can be considered a CoP (Lave & Wenger, 1991; Wenger et al., 2002) because the team engages in the LS process to collectively deepen their understanding of teaching and learning (i.e. joint enterprise) (Anfara et al., 2009; Elkomy & Elkhaial, 2022; Gruber, 2019). The team draws on what they know in order to facilitate their learning (i.e. shared repertoire). Integration of opportunities for GTAs to share their experiential knowledge ultimately helps re-define who GTAs are within the instructional team and positions them as core participants in their own PD (i.e. mutual engagement). As Dudley (2014) stated, "all members of the LS group are equal as learners, whatever their age, experience, expertise, or seniority in school (or beyond)" (p.7). Dotger (2011) described how GTAs engaging in LS without faculty created discomfort in the GTAs because they were developing new ways of thinking about teaching and learning that were different than the perspectives of faculty. In this dissertation, the instructor of record and the GTAs were engaging

in the LS together, making them all one CoP rather than the two separate CoPs as was described by Dotger (2011) . Positioning GTAs as knowledgeable helps in (a) reducing tensions that GTAs may feel with faculty, (b) professionalizing the GTA role, and (c) forming one unified CoP.

Design Feature 3

In the observation and debrief of the teach phase, provide scaffolds (e.g. observation guides, reflection and discussion prompts) for the instructional team to focus on student learning.

In traditional LS, the plan phase typically includes an extensive discussion on the instructional team's data collection plan. Also known as *points of evaluation*, a data collection plan identifies moments in the lesson where the instructional team gains insight into the thinking and learning trajectory of students in the lesson (Stepanek et al., 2007; Takahashi & Yoshida, 2004). These points of evaluation will serve as pieces of evidence that the instructional team can use in the debrief of the lesson to confirm or disconfirm if they have achieved their goal. The inclusion of tools (i.e. observation guides, reflection prompts) during the teach/observation phase and discussion prompts in the debrief of the lesson is not a novel idea, since it is typically included in the traditional LS model. However, higher education LS facilitators may need to consider a higher responsibility with providing these tools and prompts for the team.

In the context of the modified LS implemented in this study, I found that establishing points of evaluation during our plan phase was difficult because of (a) the rapid LS cycles requiring the plan phase to stay within a 30-minute time frame, which was often used to discuss certain activities; (b) the GTAs chose to not create a shared lesson plan that everyone would follow, rather they opted to do similar teaching approaches; and (c) the virtual learning environment. Because of the limited time the instructional team had for the plan phase, our

discussions rarely reached a stage when we would plan for these points of evaluation; conversations would mainly focus on identifying a real-world application of the content to introduce the main scientific concepts of the lab. Additionally, the GTAs showed resistance towards creating a shared lesson plan. Dotger (2011) has previously described this as a negative impact on the LS process because it was more difficult to evaluate the teaching recording. As similarly described by Dotger (2011), while I encouraged the team to write out a formal lesson plan, the GTAs were not required to write one. Hesitance in creating a lesson plan could be attributed to the lack of experience STEM GTAs have in writing them (Borko & Livingston, 1989; Schussler et al., 2015). Therefore, I shouldered the responsibility of creating an observation guide for the teach phase to use when watching the teaching recording.

Enactment in LS

While I presented an observation guide in Chapter 4, there were actually two iterations of the observation guide throughout the study. Figure 6.1a is the observation guide that I used in Course 1's first LS cycle teach phase. Figure 6.1b is the observation outline that I used in the remainder of Course 1 and Course 2's LS process. As I described in Chapter 4, the questions presented in the observation guide were different between Course 1 and Course 2 because their student development and equity themes were different; however, a similar question was posed for each of the instructional teams. Note in Figure 6.1a, the fifth column in the observation guide asks the instructional team to ponder over the discourse moves that the GTA implemented in the teaching recording. This column was introduced because discourse moves (Kranzfelder et al., 2019) were discussed in the first LS cycle. However, in the debrief of the lesson, when I asked for pieces of evidence in the teaching clip that would suggest if we achieved or did not achieve our research themes, the instructional team focused their discussion on the teaching moves that

Natia did and measured student learning by the amount of student engagement and participation Natia received in her teaching clip:

> Natia: For this week, I think it went pretty well. In the beginning, I warned students that I would ask them questions, so I think they actually asked a lot more questions than they would usually ask. So I think there was a really successful part at the end, when I was asking questions, they actually participated, and most of their answers were right, correct. I kind of felt accomplished at that part.
>
> Freddie: Great job, Natia. I am really impressed by your skill set because it's really clear. You didn't hesitate waiting for [student name] for an answer. And it's like, an awkward situation when you're calling out the name and the person is not answering. I had the same situation in my class.
>
> Prof. Martin: I loved it, and I was like cheering you on when you're like, giving positive feedback, even when a student wasn't like really sure, you said, "Yes, this is what it is" and kept the conversation going. You even checked the chat and you're like, "Oh hey [student name]. Great job." Positive feedback is so important. I love this. It was so great. I love the way that you were engaging with the students. You were calling on them. You were checking chat, which I know is so difficult to do, especially when you are thinking of something and then you look and your thoughts disappear. I've done that. And you confirm students' answer and still explain the concept like, "Yes, good job. It's non-polar" and still explained it for students who might not have understood it. (Course 1, Meeting 3, July 9)

In this excerpt, we learn that the instructional team was really focused on what Natia was doing to interact and engage the students, rather than on how students were thinking about the topic, as is the purpose of LS. There are multiple reasons for why this may have happened. The first reason may be because it was a column on the observation guide; since Natia's behaviors were the most observable aspect of the teaching video, the instructional team members may have found it the easiest to take note of. The second reason may be because I facilitated a discussion on discourse moves during the study and plan phases of LS cycle 1, which may have prompted the instructional team to discuss these during the debrief. The third reason is because of the

probable lack of experience the instructional team has with engaging with student ideas. Scholars have previously reported that there is a need for higher education science instructors to focus more on students developing a deeper understanding of scientific concepts and less on simply creating a repertoire of science facts (Tanner & Allen, 2006). However, didactic lectures continue to dominate STEM college courses (Stains et al., 2018), which may suggest the use of teacher-centered strategies that ultimately prohibits opportunities for instructors to learn more about how students think about a topic. Instructors can comment about how they teach because of their experiential knowledge, so prompts requiring the instructional team to consider student thinking can be easily deflected to discuss their own teaching behaviors and how they feel like students are responding to them (Ingram et al., 2004).

I brought my concerns to my reflective partners, who also expressed that unfamiliarity with engaging with student thinking may be a reason why the focus of the discussion was centrally located on teacher behaviors; however, one of my partners brought up the idea on how a focus on student engagement and responses to the instructor could be a stepping stone for the instructional team to talk more about the students (Researcher Field Notes, July 15). Thus, I revised the observational guide for subsequent LS cycles to reflect that in Figure 6.1b. My decision was to introduce a broad prompt to ease team members into adopting a student perspective. As a result, in the debrief of the teaching recording in Course 1's second LS cycle, while there was still attention focused on Freddie's practices and behavior, there was also a small discussion about student thought processes in solving content.

I will now provide some context for the next excerpt. The focal lab for the second LS cycle was focused on identifying an unknown metal carbonate, and we observed Freddie's lesson for the teach phase. In Freddie's lesson, she introduced the difference between theoretical and

experimental yields by discussing an example scenario of going to the grocery store and buying a pack of dumplings that contains six servings with three dumplings per serving (i.e. theoretical yield of 18). However, when you get home and open up the dumplings package, you only count 16 dumplings (i.e. experimental yield). Then, Freddie continued the lesson by relating this example to calculating the theoretical yield for the lab. While doing example problems, Freddie called on students to help her through the problem-solving process. When Freddie introduced one way of calculating the theoretical yield, one student offered a different approach to solve a subsequently posed problem.

After viewing Freddie's teaching clip in Meeting 5 as described above, I asked the instructional team for evidence in the clip that could be used to evaluate if we achieved or did not achieve our research themes. The following conversation ensued:

> Prof. Johnson: Those are some pretty good students. They got it down.
>
> Freddie: Yeah. I feel like they're always involved and, even though I don't see them actually doing it, I feel like they are actually writing the problem down. I expected [student name] to tell me to figure out the PO_4 molar mass, just like what I would do, and then divide by the total molar mass, but she told me to just go ahead and add the phosphorous percent plus oxygen. I might not have mentioned that so that helped me to tell the students you can do it in different ways.
>
> Prof. Martin: I think it really showed that the students understood the material. And it really showed that they were engaged with the material.
>
> Prof. Johnson: Isn't that beneficial for the students? And how they feel when you just acknowledge the different way of problem solving instead of just saying, "No, you should have done it this way." (Course 1, Meeting 5, July 23)

When I compare this dialogue to the debrief in Meeting 3, there was more of a focus on relating how student responses to questions reveal how they are thinking about the content, as evidenced by the above excerpt. While the debrief still does not take a deeper dive into the entire student

problem-solving process, there are hints that the instructional team members are considering the relationship between student responses and student thinking.

While this modification in the observation guide did not completely change the nature of the debrief conversation, it did shed light on the importance of facilitator-provided tools for the instructional teams. Returning to how the virtual learning environment may have prompted the instructional teams to focus on teacher behaviors, it is important to consider that the instructional teams' access to student thinking was typically collected when a GTA posed a problem and asked for a solution. While students responded to the questions by unmuting or through chat, what the GTAs, and subsequently the observing members of the instructional team, received were the final answers (instead of student work). Studying student work and following students' problem-solving process typically serves as the evidence LS teams use to evaluate the achievement of their goal (Fabrega, 2020; Lewis & Hurd, 2011; Saito et al., 2008). I suspect that a combination of the lecture-dominant approach to science teaching, as well as the virtual learning environment, restricted the instructional team from gathering student thinking in different methods. For future facilitators using LS in a virtual environment, I would encourage the introduction of online tools that allow students to work on a problem in-real-time and enable instructors to access the work as it is being solved. Such tools that became prominent during the remote learning environment associated with the COVID-19 pandemic setting include Google Docs (http://docs.google.com/), Google Jamboard (https://jamboard.google.com/), Nearpod (nearpod.com), and Desmos (desmos.com). By posing a problem and requiring students to show their work using these resources, instructional team members will have better access to student thinking compared to simply viewing student final answers in chat. With facilitator prompting

and access to student work, I suspect that higher education instructional teams can better ground their lesson debriefs in student thinking.

a

Approximate Time	Learning Task	Point to note regarding student development theme	Point to note regarding equity theme	Discourse moves noted	Observer notes	Wonderings
		What evidence do we note that can confirm or disconfirm that students are not just memorizing the content?	What evidence do we note that provides evidence that students are collaborating with one another and building their STEM identity?	What types of discourse moves did [name of GTA] do? How did students react?		What other questions do you have?

b

Approximate Time	Learning Task	Point to note regarding student development theme	Point to note regarding equity theme	Student thinking	Additional observer notes	Wonderings
		What evidence do we note that can confirm or disconfirm that students are thinking critically about science?	What evidence do we note that provides evidence that students are collaborating with one another? That their STEM identity is being fostered?	What does this clip tell us about student thinking?		What other questions do you have?

Figure 6.1: Evolution of observation guide

Design Feature 4

In the reflection phase, encourage continuous implementation and evaluation of teaching strategies to emphasize teaching as research.

Teaching as research is the idea that instructors are in positions to engage in answering questions that they have about teaching and learning (Duckworth, 1986). Instructors who view teaching as research are inquisitive about how students learn a topic, what teaching strategies are most effective, why some students are more engaged than others, and much more; they use their own classroom and their capacities in order to further their understanding of such areas by making observations, asking questions, and implementing and evaluating certain teaching strategies (Duckworth, 1986). While the idea of teaching as research was born in the K-12

education research sphere, it has also been taken up by leaders, practitioners, and researchers in higher education. The Center for the Integration of Research, Teaching and Learning (CIRTL) was established to focus on preparing future STEM faculty during their graduate education and postdoctoral experiences (https://www.cirtl.net/). One of the three core ideas that CIRTL promotes includes teaching as research (alongside learning through diversity and learning communities) in an effort to encourage STEM instructors to intentionally implement and reflect on teaching strategies to improve the teaching and learning experiences for both the students and themselves.

Teaching as research is an already assumed disposition in LS because of the nature of the model and the K-12 setting. Within the U.S. context, LS is not mandatory and teachers willingly engage in the LS process because of their own motivation to improve their practice; thus, LS often represents a grassroots movement organized by the teachers (Lewis & Hurd, 2011). "LS is teacher-directed and teacher-driven" (Lewis, 2002a, p.15) because the process centers around a question or challenge raised and investigated by the teachers on the LS team. In this way, their practice is their research. However, this same intrinsic motivation may not be present within every member of the LS team when implemented in higher education. For this dissertation, I chose to implement LS at the instructional team level, so the only buy-in I needed in order to proceed with my study was from the instructor of record as this was the model she willingly chose to guide her weekly GTA meetings. I recognize that this implementation of LS was mainly directed and driven by me, as the facilitator, and Prof. Martin, as the instructor of record. While the GTAs in this study consented to participating, it is uncertain if they would have opted to participate in this model if the opportunity arose outside of their research or teaching

responsibilities, especially since I did not specifically measure intrinsic motivation or level of buy-in for each GTA.

While the LS may not be GTA-directed and GTA-driven, the LS model still has the potential to deepen their understanding of teaching and learning. The notion of the research-teaching tradeoff, as described in the literature in Chapter 2 and in the department of study in Chapter 5, may imply that their disciplinary research takes precedence over their teaching PD and responsibilities (Brownell & Tanner, 2012; Connolly et al., 2016). Such an attitude may create varying levels of teacher identity among GTAs (Corrales & Komperda, 2022). Yet, a way to relieve the research-teaching tensions that graduate students report (Beath et al., 2012; Reid & Gardner, 2020; Zotos et al., 2020) could be through the understanding that teaching is research. The systematic scientific method that often guides disciplinary research can also be applied to teaching, and LS provides an ideal model for GTAs to make that connection. It is, therefore, why I chose to explicitly call out the idea of teaching as research as one of the design principles for LS in the higher education and GTA context.

Enactment in the LS

During LS, there were two categories of prompts that I used to guide the discussion. The first set of reflection prompts encouraged the instructional team to think specifically about the teaching clip and the evidence they observed in the clip that related to student thinking in order to determine if the lesson met the research themes:

1. Describe your observations of student learning. Include details of what students said, did, and wrote/produced.
2. Were there any unanticipated student responses?
3. To what extent were the goals of the lesson achieved? What evidence from the teaching clip supports your claim?
4. Which instructional decisions (from our lesson plan or on-the-spot) might have contributed to helping students meet these goals?
5. What aspects of the goals were not achieved?

6. Which aspects of the lesson should be reconsidered based on this evidence?

However, what I want to highlight, especially with this design feature is this second set of questions. The second set of reflection prompts asked the instructional team to think beyond the focal lesson and consider broad takeaways from watching the lesson and from our discussions:

1. What are some ideas that we want to takeaway for future instruction?
2. Based on our discussion, what specific ideas and strategies do we want to try and implement in our next lesson?

As facilitator, it was important that I took note of what each team member said, especially because it sometimes differed for each person. Then, I would purposefully bring in the ideas and strategies that were mentioned into subsequent meetings. This helped to facilitate the discussions for the study and plan phase for the next cycle, as well as enabled its evaluation in the following teach and reflect phase. Given the rapid LS cycles in this modified model, the GTAs were able to identify a practice they wanted to use, implement that practice, and evaluate and reflect how students responded to that practice at least once during the academic term. Such a structure helps to encourage the idea of teaching as research and normalize continuous teaching professional development.

When asked about the reflect phase in their post-participation interviews, all the GTAs mentioned that the reflect phase was important for any instructor to evaluate their own teaching practice. For example, when prompted to talk about the reflect phase in her post-participation interview, Narcissa from the Course 2 instructional team responded with the following:

> I mean, you have to reflect, right? You do a study and, at the end of it all, when you're trying to assess something that you're doing, and you try out different things, and you see what happens from it. You collect your data then you have to reflect on the data and analyze and see like, 'Okay, what worked? What didn't? What helped? What didn't you know? How can I take what I've went through and use it in a way that helps me become a better teacher, or even just a better person.' Because really, if you don't want to teach, you still end up teaching new

> employees, or in lab like undergrads, so it applies. I think it's pretty critical. I think the whole way [the LS] was conducted, all together, made a lot of sense to me. And it really came full circle. (Narcissa, Post-participation interview, August 13)

In this excerpt, Narcissa used language in which she compares the LS cycle to research. Narcissa also stated that engaging in LS was not only beneficial for the graduate students who planned on pursuing a career in teaching in the formal education setting, but also for others who pursue research in an industry or academic setting because they will interact and mentor others.

The idea that teaching is research also came about with the Course 1 instructional team. For example, when prompted to discuss the reflect phase in her post-participation interview, Natia said the following:

> I guess that's kind of the purpose of this whole research because teachers also get inspiration from this and, like, if a [teaching] approach is good, you can end here and use it in other classes and for future. So I think it is a very significant part. Like there's no point if we just say, "This was good" and you just stop using it, right? If it's good, then you can actually show it to others and use that approach for future classes. (Natia, Post-participation interview, August 18)

Similar to Narcissa, in this excerpt, Natia used language that implied the LS process as a research experiment in which they, as the instructors, field tested a teaching approach, worked to perfect it, and shared it so that they could use it in their future instruction.

Summary of RQ3 Findings

In this chapter, I presented four design features that should be integrated when facilitating LS with GTAs and higher educational instructional teams:

1. Undergo several cycles of LS to maximize the limited amount of meeting time, enable instructional team members to field test their teaching approaches, and promote a more nuanced understanding of teaching and learning.

The first design feature not only takes into the consideration how much content is covered in higher education courses and how quickly the pace moves, but also creates ample opportunities for LS teams to try out and refine their teaching approaches. In this process, team members come to better understand the various factors that impact the relationship between their teaching and their students' learning.

2. In the study and plan phases, incorporate activities and discussion prompts that enable instructional team members to draw on their own teaching and learning experiences.

The second design feature acknowledges that team members enter the process with valuable knowledge and experiences about teaching and learning. By leveraging these knowledge and experiences in the LS, all team members are positioned as colleagues and equals.

3. In the observation and debrief of the teach phase, provide scaffolds (e.g. observation guides, reflection and discussion prompts) for the instructional team to focus on student learning.

The third design feature recognizes that engagement in student thinking and student work may not be a practice commonly used by higher education STEM instructors. Therefore, the facilitator should first shoulder responsibility in scaffolding and pushing the instructional team to discuss student ideas and examine student work.

4. In the reflection phase, encourage continuous implementation and evaluation of teaching strategies to emphasize teaching as research.

The fourth design feature acknowledges the belief of a research-teaching tradeoff that often exists in STEM fields and works to promote instructor awareness of and engagement in the scholarship of teaching and learning.

Chapter 7: Discussion

The goal of my dissertation was to determine the feasibility of implementing the LS model with higher education instructional teams, including GTAs. A handful of studies have previously described the impact of the LS model on how GTAs understand and approach teaching and learning (Collet & Peñaflorida, 2020; Dotger, 2011; Dotger et al., 2012; Lampley et al., 2018); however, rather than measure the change that occurred as a result of participation, I sought to characterize the ways in which (a) GTAs, and more broadly, the higher education instructional teams they are situated within, engage with the model; and (b) how LS mediates their interactions with one another. In doing so, I aimed to develop design features that would aid future LS facilitators who want to implement the LS with GTAs in the future.

In this discussion, I adopt a wider lens and draw on my own data as well as existing research in order to provide insight into the ultimate question: "did it work?" In this chapter, I evaluate the level of success of the LS model and reflect on my experiences as the LS facilitator to highlight the lessons I have learned.

Evaluating the Success of the LS Model

Perry and Lewis (2009) measured the success of their LS adaptation by evaluating changes and improvements "in (a) teachers' self-reported instructional practices, (b) their professional capacity, and (c) their ability to work together to improve their knowledge for teaching" (Perry & Lewis, 2009, p. 367). I adopt this same framework to guide my discussion.

Changes in Instructional Practice

The data that I present in this dissertation provide a very limited scope of GTAs' instructional practices and any changes that may have occurred. Select teaching recording clips, as volunteered by the GTAs in the teach phase, served as the main source to observe

instructional practices. This is in contrast to Dotger's (2011) LS model where the study's researcher observed each GTA's research lesson. However, the discussion in all phases of my modified LS model invited all members of the instructional team to self-report their instructional practices and any changes to their teaching approaches. In fact, this was explicitly encouraged during every reflect phase; I asked the other GTAs how the lesson plan was received in each of their own discussion sections, even if they were not the observed GTA. GTAs were also prompted to discuss changes in their beliefs and approaches to teaching in their post-participation interviews.

From the data analyzed and presented in this dissertation, I would consider the LS successful in encouraging change in GTA instructional practice and mediating what strategies GTAs considered or will consider in their teaching. Through a cultural-historical theory lens, LS can be viewed as tool that regulated how instructional team members carried out their responsibilities in the classroom. The data presented in Chapter 6, which supports Design Feature 4, revealed that the LS discussions and activities prompted GTAs to consider changes in their instruction, implement such changes in their future instruction, and reflect on how students responded to those changes. Additionally, the plan phase inherently promotes GTAs to change how they approach the introduction to each focal lab since the teams were collectively building a lesson plan together. These self-reported changes in instructional practice aligns with previous studies that have implemented LS with GTAs (Collet & Peñaflorida, 2020; Dotger, 2011).

Furthermore, I would take this further and claim that the modified LS in this dissertation was also successful in deepening the GTAs' understanding of teaching and learning. While I did not measure conceptions of teaching pre- and post-participation, the data presented in Chapter 4 revealed that members of the instructional team were engaging with and adopting four different

perspectives of teaching throughout the LS. I argue that exposure to these different perspectives deepen one's understanding of teaching and learning because they are more likely to recognize just how multifaceted teaching is. A deeper understanding of teaching was also previously reported as a result for GTAs participating in LS (Dotger, 2011; Lampley et al., 2018).

Different models of and approaches to GTA PD encourage the promotion of changes in teaching beliefs and practices (Baumgartner, 2019; Bowman et al., 2019; Lang et al., 2020; Reeves et al., 2016). While LS can be added to this list as just another approach to GTA PD, I believe that LS also offers more, as detailed in the next two sections.

Changes in Professional Capacities

As reported by Jacobs (2002), GTAs hold a number of responsibilities including lecturing, overseeing labs, mentoring students, and grading assignments, among others. The nature of these responsibilities suggest that while graduate students enter their programs to pursue disciplinary research, they also engage in many different facets of teaching (Reid & Gardner, 2020). Departmental and institutional norms, especially within STEM disciplines, can often communicate the research-teaching tradeoff, placing the research responsibilities and the teaching responsibilities of graduate students in conflict with one another (Beath et al., 2012; Brownell & Tanner, 2012; Colbeck, 2008; Hattie & Marsh, 1996; Zotos et al., 2020). Graduate students report receiving mixed messages on the importance of teaching, where the importance of research often prevails over teaching (Reid & Gardner, 2020). However, it is important for graduate students to recognize the synergistic nature of research and teaching (Light & Calkins, 2015; NASEM, 2018). Gilmore et al. (2014) reported that graduate students do indeed acknowledge the relationship between research and teaching, but typically observe the unidirectional ways research can inform or enhance their teaching skills. I argue that the LS

model offers GTAs with the opportunity to build their identities as teachers in parallel with their research responsibilities.

As articulated in Chapter 5, the discussions among members of the instructional team in this study revealed that the research-teaching tradeoff is present within their department. The tension between the research and teaching responsibilities was first revealed in Meeting 1 when the teams were establishing norms and developing their research themes. More specifically, the activity where the team reviewed their department's welcome message initiated an extensive discussion that disclosed the different messages team members received about teaching from their research advisors and other GTAs, as illustrated in Chapter 5. These messages of prioritizing research over teaching are troublesome for GTAs like Margaret, who pursued graduate school in order to become an instructor, because receiving incongruent messages about their professional identities can lead to emotional exhaustion (Haines & Saba, 2012). However, from the data analyzed and presented in this dissertation, I would consider the LS model a success in promoting GTAs to recognize and reimagine their professional capacities. As articulated in the three results chapters in this dissertation, there were many points throughout the LS where members from both instructional teams, not solely Margaret, expressed appreciation for the opportunity to engage in discussions around teaching. As highlighted in Chapter 6 under Design Feature 4, Narcissa was able to draw the connection of how someone like her, who pursued graduate school for research, can still benefit from the LS experience since researchers will still need to onboard new employees or mentor novice researchers. Similar sentiments were shared by Natia, as described in Chapter 5, where engaging in LS enabled instructional team members to recognize that graduate students can enjoy and be good at teaching. Natia explained

how through the LS process, she was able to admit she enjoys teaching and she feels like she is good at it, which is an attitude that she says she has kept hidden for a while.

Additionally, as articulated in Chapter 6, the LS model also promotes the idea of teaching as research. While the research-teaching tradeoff notion may communicate to GTAs that teaching responsibilities are not a worthwhile investment of their time, LS offers a different perspective and highlights how continuous improvement of teaching practice is a form of research conducted by them within their own classrooms. Thus, rather than unidirectionally perceiving that only research can enhance teaching, GTAs can also recognize that enhancing their teaching skills improves their communication, organization, creativity, and critical thinking, all of which are relevant to disciplinary research (Feldon et al., 2011; Gilmore et al., 2014; Light & Calkins, 2015; Trautmann & Kransy, 2006). In alignment with CHAT, this realization demonstrated how the system dynamically shifted with the introduction of LS and how new norms and labor roles were created to better align with their expressed values.

As the LS facilitator, I think that one structural feature of the modified model that was particularly helpful in promoting change in the GTAs' professional capacities was the fact that the LS was integrated into their regularly scheduled weekly TA meetings. Thus, engaging in the LS was perhaps not viewed as an additional responsibility on top of their large number of research and teaching responsibilities, and it was not viewed as an activity that was competing for their time. Aside from the weekly reflection after every LS meeting (which was estimated to take around 10 minutes), members of the instructional team were not asked to do work outside of meeting time. Furthermore, the integration of the LS model into weekly meetings also offers a more contextualized PD experience that may have also contributed to a change in GTA's professional capacities. While GTAs can attend orientation (Belnap & Allred, 2009; Hardré &

Burris, 2012; Ridgway et al., 2017) and establishment programs (Belnap & Allred, 2009; Connolly et al., 2018; Schussler et al., 2008; Wyse et al., 2014) that expose them to different instructional strategies and new conceptions of teaching and learning, the modified LS model described in this study offers GTAs the ability to think about, implement, be held accountable for, reflect on, and improve a new teaching strategy, all within the duration of the PD. This was a feature that instructional team members found beneficial, as described in Chapter 6 under Design Feature 1. The opportunity to not only learn about teaching strategies but to practice and refine these teaching strategies may contribute to the development of a teaching identity and an increase in teaching self-efficacy (Connolly et al., 2018). Therefore, I suspect that LS can be a PD model that not only helps to relieve the research-teaching tradeoff tensions, but also expands GTAs' professional capacities by developing their identities as both researchers and teachers.

Changes in Collaboration

As my final measure of evaluating the success of the LS model, I consider the impact on the instructional teams' ability to collaborate and collectively build knowledge together. As mentioned in Chapter 2, faculty and peers can potentially serve as sources of teaching support for GTAs. GTAs have reported feelings of discomfort when trying to engage faculty in conversations around teaching (Seymour, 2005; Dotger, 2011) and many of the conversations surrounding teaching center logistical details rather than pedagogical skills (Hoessler & Godden, 2015; Lee et al., 2017; Nasser-Abu Alhija & Fresko, 2020). In addition to faculty, peers have been reported as a crucial supporter for GTAs in navigating their teaching responsibilities (Myers, 1994; Staton & Darling, 1989), but conversations with peers are often not facilitated in formal teaching PD structures (Corcoran & Clark, 1984; Wulff et al., 2004) and focus on logistical details and advice on issues related to teaching, such as student conflicts and grading

rubrics (Marquis et al., 2020; Mena et al., 2013). While I did not specifically measure the relationship between members of the instructional team pre- and post-participation in LS, I do believe that LS provides a formal structure for GTAs to speak with the course instructor and their peers about teaching. Furthermore, I suggest that LS shifts the conversation around teaching so rather than discuss logistics of a particular lesson or assignment, members of the team engage in discussions around student thinking and factors that impact the teaching and learning process.

As was elaborated in Chapter 4 through the case study, the conversations that the instructional teams had around teaching and learning moved beyond logistical details. There was discussion about what might impact student motivation and engagement, ways to enculturate students into the practices and norms of higher education, and strategies to make content more relevant and interesting for students. Additionally, as described in Chapter 5, the teams also discussed breaking away from departmental norms and dynamics and establishing new practices that were collectively negotiated. Prof. Martin and Prof. Johnson also willingly engaged in and contributed to these conversations alongside the GTAs; this is in contrast to the hesitancy that GTAs felt with sharing their newfound perspectives on teaching and learning with faculty members, as reported in Dotger (2011).

In the modified model described in my dissertation, the course instructor and lab coordinator engaged in the LS experience alongside the GTAs so that a new CoP, with new norms and practices, were established among them. Prof. Martin also brought a different disposition to the meetings. While previous research have reported that faculty view GTAs as faculty support (as opposed to student support) (Lee et al., 2017), there is evidence presented in this study that suggests Prof. Martin sees her GTAs as holding a responsibility to serve the students, not her as the instructor. For example, as described in Chapter 4, Prof. Martin says, “I

truly believe in building you guys up so you can build my students up, and I can build them up as well" (Course 2, Meeting 1, July 9). In this excerpt, Prof. Martin is placing the students at the center of instruction, suggesting that GTAs serve the students rather than her.

I believe that the LS model was successful at providing a structure to facilitate collaboration and collective knowledge building among the instructional teams. Returning to the three main principles of sociocultural theories of learning that was introduced in Chapter 2, I claim that LS mediated (a) how the instructional team redefined their roles and values in supporting student learning; (b) who they were discussing ideas about teaching with; and (c) what shared knowledge and teaching approaches were ultimately formed and adopted by individual team members. In this way, the LS teams became their own CoPs. I recognize that my study may present a unique context in that the course instructor willingly agreed to participate and engage with her GTAs in this process. As I described in Chapter 6, other faculty members, or even GTAs, may find it less desirable to engage in LS due to time constraints, other commitments, or alternative ways of thinking about teaching and learning. In these circumstances, I would emphasize the importance of the first meeting, where norms and expectations are established and research themes are collectively developed.

Reflections on being a LS Facilitator

Based on the discussions that I observed and participated in at the 2021 World Association of Lesson Study conference, there is a need to conduct research on the role of LS facilitators. I offer my experiences here in order to contribute to the field.

Clivaz & Clerc-Georgy (2021) suggest that a LS facilitator has four different roles: a convener, a teacher trainer, a researcher, and a group member. Using these four roles, I describe my experiences serving as facilitator in this study.

Facilitator as Convener

As convener, the LS facilitator assumes the responsibility to initiate, recruit, and collaborate with institutional leadership in order to establish the LS team and process (Clivaz & Clerc-Georgy, 2021). As facilitator, I had to be flexible in order to have the LS considered. I modified my original plan, as portrayed in Table 6.2, and had to assume a lot of responsibility, especially during the study phase as I sought examples from the literature to bring into our discussion. However, I was very intentional with what I said and how I contributed to the discussion. I presented empirical research, posed activity prompts and discussions, and suggested teaching strategies, but I did all those duties with the purpose of keeping the discussion productive.

With that, I recognize that the LS would not have been possible without me. More specifically, I was the one who was (a) knowledgeable about the LS model, (b) trained to be a LS commentator through the CANMEE program, (c) motivated to bring the LS model to the course instructor , and (d) incentivized the GTAs for their participation. If I were removed from the context, the LS model would probably not have been pursued. A similar organization is often true for LS in the K-12 setting, where facilitators are researchers who study the LS process; yet, as a team gains experience with engaging in the LS process, the team could become self-sustaining and the facilitator can be removed from the team (Lewis et al., 2019). Therefore, plans to implement and sustain LS in higher education will first require someone who is knowledgeable about the process to initiate the structure. Recognizing that my time as LS facilitator with these two instructional teams was limited to the summer term, I provided my facilitator guide, slides, and all the literature I referenced in a Google Drive folder which is owned by Prof. Martin and shared with Prof. Johnson and the GTAs. Future LS facilitators

should make these resources available to LS team members in order to encourage self-sustenance.

While LS can be implemented with individual instructional teams and facilitated by their faculty, if a broader institutional or departmental LS structure is desired, there will be more effort required to sustain such an organization, as suggested by CHAT and other sociocultural theories of learning. Turning to the Four Frames framework, changes in departmental or institutional structures, symbols, people, and power will need to be considered (Reinholz & Apkarian, 2018). Departmental authorities will need to consider what policies will encourage use of LS, such as requiring its implementation by all faculty who are working with GTAs and incentivizing faculty through stipends, awards, or service credit for those who take on leadership roles to support other faculty.

Symbols, also considered the values of the department, will also need to change. As evidenced in Chapter 5, members of the instructional team received implicit messages that communicated a devaluation of teaching; while LS could serve as a tool to shift these values, change would also need to come from the departmental level. Suggestions presented by Reinholz and Apkarian (2018) require departmental leadership to consider what ideas and events related to teaching are being promoted at department meetings. Providing time for faculty to discuss their LS journey at meetings or documenting faculty and GTA experiences in LS in a departmental blog may encourage a shift in perspective towards teaching and help to sustain LS.

Considering the agency of individual faculty and GTAs within the department, there should be regular check-ins to determine if currently implemented LS models are meeting the needs, goals, and identities of the people engaging in the process. While LS cycles are individualized to the instructional team, the course they are teaching, and the research themes

they develop, departmental leadership should modify and adapt the ways the LS model is implemented based on the collective needs, goals, and identities of those in the department.

Finally, when considering power, the LS model already promotes equal expertise among team members, as described in Chapter 6 under Design Feature 2, but equity should also be considered when attempting to implement and sustain LS at the departmental level. Using a top-down approach, departmental administration may require faculty to implement LS with their GTAs, but administration should provide opportunities for faculty and GTAs to voice their concerns over the responsibilities, time commitments, and effort that are associated with it, and work with faculty and GTAs to establish a model or structure that integrates their perspectives. Using a bottom-up approach where faculty or GTAs drive the implementation of LS, departmental administration should welcome their perspective and work to develop a shared vision to create structures that support their efforts.

Facilitator as Teacher Trainer

The facilitator role as teacher trainer suggests that the facilitator is knowledgeable about the scholarship of teaching and learning, evidence-based pedagogy, and learning theories (Clivaz & Clerc-Georgy, 2021) and strategically leverages this knowledge to productively guide conversations. Before and during my role as LS facilitator, I was overly cautious of not wanting to simply disseminate best teaching practices. It is for this reason that I created the facilitator guide (Appendix A), which would allow me to intentionally plan when I would present information and what probes I could use to push thinking forward. However, as I wrote the facilitator guide, prepared for LS meetings, and made in-the-moment decisions, I had to constantly re-center my perspective and remind myself that LS is "teacher-directed and teacher driven" (Lewis, 2002a, p. 15). A frequent conversation I had with my reflective partners during

the data collection process was, “How much should I push them?” This is a question often raised by all PD facilitators, not just LS facilitators (Hmelo-Silver, 2004; Zhang et al., 2011), especially because too much push may introduce tensions between facilitator and team members (Becuwe et al., 2016). In this study I aired on the side of “pushing less” as evidenced by my decision to not mandate shared lesson plans or require more extensive responses in the observation guides and brainstorm documents. Studying this decision making process will be important in characterizing the LS facilitator role.

Facilitator as Researcher

The LS facilitator takes on two levels of a researcher role: (a) a member of the LS team who adopts a research stance to engage in the study, planning, and evaluation of a particular lesson; and (b) an academic researcher studying the team members or the LS process (Clivz & Clerc-Georgy, 2021). In my dissertation, I engaged in both researcher roles. Recognizing that my role as an academic researcher studying the LS process may interfere with the goals and interests of the instructional team, it was important that I had my reflective partners to make sense of situations and data. My reflective partners provided additional perspectives to ensure that I was not interpreting scenarios with biases that I may be bringing in. Additionally, re-centering my perspective to place the instructional team at the focus of all my decisions, as described above, alleviated any tension that I felt with holding both researcher roles. I adopted the stance that my dissertation was seeking to determine if LS could even work in this context, which I frequently relayed to the instructional team both in meetings and in post-participation interviews as to not bias their own attitudes, behaviors, and responses.

Facilitator as a Group Member

The final role that LS facilitators take on, as suggested by Clivaz & Clerc-Georgy (2021), is the role of a group member, which can often be the most difficult role to assume because team members may expect facilitators to disseminate their knowledge and create a list of best practices for instructors to remember. It is for this reason why I have highlighted the use of experiential knowledge as Design Feature 2. By providing opportunities for the instructional team members to claim and share their experiences, I positioned them as experts and myself as a group member who was eager to learn about their ideas and strategies.

Chapter 8: Conclusion, Limitations, and Future Directions

In this chapter, I conclude my dissertation by first summarizing the findings for each of my research questions. Then, I articulate the limitations of my study context and design, as well as suggest potential directions for future research.

Summary of Findings

RQ1: Teaching Perspectives during LS

What teaching perspectives are the instructional team operating from throughout the course of the LS? The findings of RQ1 suggest that the instructional team studied in this dissertation operated from the transmission, apprenticeship, developmental, and nurturing perspectives. The transmission perspective seemed to be a default way of thinking about teaching, which may be an artifact from prior teaching and learning experiences within STEM disciplines. The apprenticeship perspective was prominent when the instructional team was developing their research themes because the team's overarching goal for students was to enculturate them into thinking, talking, and acting like a scientist. The developmental perspective was promoted by the overall structure and nature of LS as the instructional team were prompted to anticipate student thinking and then plan for how they would respond. The majority of contributions of the nurturing perspective seemed to come from a certain individual on the LS team, suggesting that individual team members and their values and beliefs greatly impact LS discussions and team dynamics. The nurturing perspective also appeared frequently in the reflect phase as team members often commented on the how certain instructional moves influenced student attitudes. The RQ1 findings suggest that LS acts as a structure to activate multiple teaching perspectives, enabling instructional teams to develop a multifaceted understanding and approach to teaching and learning.

RQ2: CHAT Lens on LS

What are the communities, division of labor, and norms that impact the ways instructional teams engage in LS? Adopting a CHAT lens helped me identify two conflicting activity systems that the instructional teams were engaged in. The first system is the LS system which is comprised of the instructional team (i.e. GTAs, course instructor, lab coordinator) and me as the facilitator. The second system is the departmental system which includes the instructional team, other GTAs who are not participating in the LS, and research advisors (i.e. other faculty). While the two systems have a shared object of supporting student learning, my analysis suggests that implicit departmental norms and dynamics regarding teaching do not align with the values and beliefs of the instructional teams. Thus, through LS, the instructional teams explicitly co-constructed new norms and dynamics.

While the department system encouraged GTAs to spend minimal amount of time on their teaching responsibilities, the LS system insisted that GTAs have important teaching roles and that devoting time to learn about and develop into these roles are worthwhile. The LS team also emphasized that teaching is important and GTAs are allowed to enjoy and be good teachers while also being graduate students. The department system conveyed teaching as a non-collaborative effort, but the LS system contrasted this and underlined the importance of sharing and learning from others' ideas and experiences. Finally, the department system also suggested a deficit perspective of students and communicated that students do not put in effort towards their own learning. In contrast, within the LS system, these assumptions were challenged and the instructional teams ultimately came to understand that students need guidance on how to be successful in college. The RQ2 findings suggest that LS enables instructional teams to confront

implicit values and assumptions about teaching and develop new ways of thinking about teaching.

RQ3: LS Design Features

What design features support the implementation of LS with higher educational instructional teams? Informed by the data analyzed in this study, my experiences, and existing theoretical and empirical research, I suggest four design features that support LS with higher educational instructional teams:

1. Undergo several cycles of Lesson Study to maximize the limited amount of meeting time, enable instructional team members to field test their teaching approaches, and promote a more nuanced understanding of teaching and learning.
2. In the study and plan phases, incorporate activities and discussion prompts that enable instructional team members to draw on their own teaching and learning experiences.
3. In the observation and debrief of the teach phase, provide scaffolds (e.g. observation guides, reflection and discussion prompts) for the instructional team to focus on student learning.
4. In the reflection phase, encourage continuous implementation and evaluation of teaching strategies to emphasize teaching as research.

These four design features work together to address the contextual constraints of higher education and scaffold the LS process to engage instructors in their own development as teachers. These four design features emphasize opportunities for instructional teams to shift their attitudes towards teaching and develop their teaching skills.

Limitations and Future Directions

Remote Setting

While not entirely considered a limitation as virtual LS has been reported to be a productive medium (Soto et al., 2019), the remote setting for both the course and the LS meetings due to the COVID-19 pandemic may have impacted the ways in which the instructional teams engaged with me and the LS process. Particularly relevant to the LS process, I found it challenging to promote engagement with student work because the GTAs typically garnered student participation by posing a question and asking for an answer verbally or in chat. This made it difficult to stay true to the LS model as student thinking and work no longer was the center of the discussions. Suggestions to address this limitation are articulated in Design Feature 3 in Chapter 6.

I also recognize that the emergency remote learning environment may have left members of the instructional team feeling exasperated and exhausted, potentially impacting the thoughts and attitudes they contributed, especially during the establishment of norms and developing the research theme. Such feelings could have been a reason why the instructional team pushed back against departmental norms and dynamics, as described in Chapter 5. Lack of student participation in virtual settings could also contribute to feelings of frustration, which impacted LS discussions as the conversations often centered around finding ways to increase student participation. Yet, this frustration could have also served as motivation for the instructional team to put their all into the LS cycle and improve their teaching, as was implied by Narcissa described in Chapter 5. Thus, it is difficult to pinpoint if the instructional team's motivations, intentions, and goals for participating in the LS would have been the same had this study not

taken place during the COVID-19 pandemic, which is why I am including this commentary in the limitations section.

The virtual setting also afforded different opportunities and resources, such as ease of accessing teaching recording clips and multiple formats to contribute to discussion (i.e. chat, Zoom reactions, etc.), which enhanced the LS process. As with much of the research being investigated and published currently in the education research field, it would be important to consider what factors in a virtual setting should be retained and expanded upon even after returning to in-person LS meetings.

Study Design

A second limitation of this study is attributed to study design. My data sources and analyses focused on characterizing the discourse that occurred in the LS meetings, the reflections of the GTAs post-participation, and my field notes. I did not attempt to formally measure change in beliefs or practices through pre- and post-interviews or pre- and post-surveys; rather, the changes that I reported in Chapter 7 are from my analysis and interpretation of the dialogue, attitudes, and behaviors of the team. My reasoning behind not investigating change through such formal measures is because of the short duration of the study (i.e. seven-week PD for Course 1 instructional team, five-week PD for Course 2). Advised by my dissertation committee and supported by empirical evidence, sustainable change in both teaching perspectives and practice takes time (Supovitz & Turner, 2000; Lee et al., 2008; Marx et al., 1998); therefore, I would not have expected a measurable change in instructional team members in this short time frame. Future research should investigate the changes in both teaching perspectives and practice with higher education instructors who engage in LS for longer periods of time.

Role of Facilitator and Researcher

The final limitation I want to highlight is my dual role as facilitator and researcher. Serving as both the LS facilitator and study researcher has afforded me with opportunities to more deeply understand the context and constraints that impact the ways in which instructional team members interact with one another and the LS model. For example, my decision to explore RQ2 was because of the insight I gained sitting as a group member in these discussions. However, I also recognize that my role as a researcher may have impacted what instructional team members shared in discussion and in post-participation interviews. Additionally, while I had reflective partners in place to guard against my personal biases as the study researcher, my interpretation and presentation of the data may still have been impacted. Therefore, future research might choose to explore how instructional teams engage with the LS cycle when the facilitator and study researcher roles are held by two different individuals. More generally, there remains many questions about the role, responsibilities, and impact of the facilitator in the LS process. I join others in my field to call for research that demystifies and characterizes the multifaceted and complex role of facilitator.

Concluding Remarks

This dissertation provides the resources, experiences, and characterization of a LS model implemented with two higher education instructional teams teaching virtual introductory chemistry labs. The sociocultural lens applied to the study design and analysis offered a perspective that enabled me to consider the ways the LS model facilitated and mediated different teaching perspectives (RQ1), as well as new community norms and dynamics (RQ2). In this dissertation, I also more broadly reflected on the implementation of the LS model to glean design features that should be considered by future LS facilitators who intend to work with GTAs or

higher education instructors (RQ3). Based on my findings, I believe that LS has the potential to be an effective and successful PD model for GTAs and higher education instructional teams as it not only supports individual team members in deepening their understanding of teaching and learning, but it also demonstrates great promise for promoting collaboration and shifting attitudes and culture around teaching.

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Appendix A: LS Facilitator Guide

Summary of timeline:

Week 1: Establishment of group norms and the generation of student development and equity research themes
Week 2: Study and plan phase for lesson topic of Week 3
Week 3: Teach and reflect phases for Week 3
Week 4: Study and plan phase for lesson topic in Week 5
Week 5: Teach and reflect phases for Week 5
Week 6: Study and plan phase for lesson topic in Week 7
Week 7: Teach and reflect phases for Week 7
Reflect on entire LS process

(5-week term will only complete two lesson study cycles)

Week 1

Key Activities:

- 1.1 Identifying group norms
- 1.2 Identifying research themes
- 1.3 Introduction of weekly reflections

1.1 IDENTIFYING GROUP NORMS

In-meeting activity (10 min)

Purpose of assignment: Enable individuals the opportunity to idealize their lesson study experience and their team.

Instructions: Create one Google slide in which you drop in images, quotes, and words that represent your expectations for participating in this professional development. Be sure to include a representation of some characteristics of the kind of team you want to be a part of.

As you make this slide, think about the following questions: (Stepanek et al., 2007)

1. What are your expectations for how we will work together?
2. What conditions will contribute to our learning and growth as instructors?
3. What conditions do you expect will get in the way?
4. What strategies should we use to resolve differences and disagreements?

Once you have finished making your slide, please write about your slide in the "notes" section. Describe why you chose these images, quotes, and words to represent your expectations of the professional development and of the team.

Have each member share out.

In-meeting activity (15 min)

Purpose of activity: Lesson study creates a community in which everybody has expertise that will make this successful. Thus, it is important to create and maintain these norms in order for everyone to feel comfortable and valued for sharing their knowledge and expertise.

Instructions: Present list of effective group norms as described in the literature:

Example #1 (Lewis, 2002b)

- Communicate clearly and listen carefully.
- Respect the views of others.
- Share your views willingly.
- Ask and welcome questions for clarification.
- Be open to the ideas and views presented.
- Honor time limits.
- Stay on task.

Example #2 (Stepanek et al., 2007)

- Communication is open and honest.
- There is a climate of trust.
- Members are encouraged to both challenge and support one another.
- When resolving conflict, members must agree to listen and focus on the problem rather than on the people involved, give adequate processing time, and try to see the issue from the other person's perspective
- Mistakes are viewed as opportunities.
- Members are held accountable for their actions, thus members should be committed to fulfilling their responsibilities, dividing the workload, and respectively supporting each other.

Group discussion prompts:

- Is there something you had on here that you suggested in your slide?
- Is there something not on here that you would like to add?

Synthesizing our discussion:

- Create a Google doc with a list of our norms and expectations

Concluding points:

- **Egalitarian discussion** (Lewis, 2002b): This professional development may operate differently from other opportunities that you've had. I want to emphasize that every individual in this group has something valuable to contribute to the process and study. After all, you all have once been students and you all are continuing to learn.
- **Emphasis on students, not teachers** (Lewis, 2002b): Reminder that as we move forward, though we are instructors of the students and are meeting together, this opportunity is not a critique of you and your practices. We are together trying to learn more about how students learn the material.

1.2 IDENTIFYING RESEARCH THEMES

In-meeting activity (25 min)

Purpose of activity: A research theme, or sometimes called a research focus or a main aim of the lesson study, is a broad, long-term goal that instructors wish for their students. A ***student development theme*** refers to the goal that instructors may have for students regarding their development as learners in higher education. Some examples include "building a desire to learn" or "developing independent thinkers." An ***equity theme*** refers to the goal that instructors may have for students addressing equal opportunities for access and success. Some examples include "building a sense of agency in their career path" or "validating their STEM identity."

Instructions: Present departmental mission statement of the instructional team.

Individual reflection then whole group discussion prompts:

- After reading this document, what are the parts you feel are most important or most interesting?
- From your own experiences, what part of the mission statement do you think needs the most improvement?

Instructions: Have a "brainstorming" Google Doc that everyone can contribute to in order to document the ideas from the discussion. Start to formulate possible research themes.

Individual reflection then whole group discussion prompts:
Think about a class of students that you have recently taught. Or perhaps from your own experiences when being a student and your classmates around you.

- What are the resources that students have and bring to the course?
- What can we, as instructors, do to elevate these assets to support and help develop these students towards the goals we have identified?

Synthesizing our discussion:

- Develop the LS research themes and document it in the brainstorm document
- Collect thoughts on if every team member agrees with the final theme

1.3 INTRODUCTION OF WEEKLY REFLECTIONS

In-meeting activity (10 min)

Purpose of activity: The purpose of these weekly reflections is to allow you space to critically think about your experience and development throughout this process. The weekly reflection will give you space to do a "brain dump" where you can express how you feel and any thoughts you may have had about the activities we engaged in during the meeting. Additionally, this will give you the opportunity to individually let me know if you felt like you were heard or if you perceived ample opportunities to contribute to the process. This will help me better understand what I can do to support and maintain the norms each meeting. After each meeting, take about 5-

10 minutes to complete this reflection. You will be compensated for this additional time outside of the meeting.

Instructions: Present form for weekly reflection. Facilitate a discussion to raise and answer any questions and address expectations.

Week 2, Week 4, Week 6

Key Activities:
- 2.1 Studying the lesson
- 2.2 Considering student-centered teaching strategies
- 2.3 Planning the lesson

2.1 STUDYING THE LESSON

In-meeting activity (30 min)

Purpose of activity: Lesson study is not about re-inventing the wheel, rather it is about designing effective instruction for our own students. Considering how you were taught the content topic or how you first taught the topic is a good starting point.

If first study phase:
Display the following terms:
- Alternative conceptions
- Partial understandings
- Misconceptions

Individual reflection prompt then whole group discussion:
- What is the meaning of each word?
- Are there any similarities or differences between each term?
- What do each of these words imply?

Display the Teacher Noticing Framework (Jacobs et al., 2010)
- Attending to students' strategies
- Interpreting students' understandings
- Deciding how to respond on the basis of students' understanding

Individual reflection then whole group discussion prompts:
Reflect on your time as student first learning about [topic], or your first time teaching [topic]:
- Were there certain concepts or constructs that were confusing or difficult to grasp? What were they?
- Why do you think they were confusing or difficult to grasp?

Instructions: Facilitator provides a multi-step problem that integrates several concepts from the topic. Ask the team to individually complete the problem. Then, purposefully give a reasonable incorrect answer (where the incorrect answer reflects that of a partial understanding or misconception of a concept). Ask the team to consider how the student may have approached the problem.

Example below for limiting reagents lab:

> The following reaction is used to obtain small amounts of chlorine gas in the laboratory:
> $$MnO_2(s) + 4HCl\ (g) \rightarrow MnCl_2\ (s) + Cl_2(g) + 2H_2O(l)$$
> If 28.0 g of MnO_2 are allowed to react with 42.0 g of *HCl*, what is the limiting reactant?

Incorrect student answer: MnO_2

2.2 CONSIDERING STUDENT-CENTERED TEACHING STRATEGIES

Engage in the following section if this is your team's first study phase

Purpose of activity: Lesson study emphasizes the ideas and the perspectives of the students. It is important for instructors to create opportunities for students to express these ideas and perspectives then use these to respond and push the lesson forward.

Instructions: Facilitator gives brief overview of teacher discourse moves and its importance in engaging students in the construction, justification, and evaluation of knowledge rather than the dissemination of facial knowledge. Examples of discourse patterns:

- IRE (Initiate-Response-Evaluate)
- IRF (Initiate-Response-Feedback)

Introduce the CDOP (Classroom Discourse Observation Protocol) coding scheme (Kranzfelder et al., 2019).

Individual activity: Provide the following document Getting Started With Active Learning. Identify 2-3 teaching strategies from this document that you may want to implement in the lesson. Record your ideas in the "Brainstorm" Google Doc and how you might adopt the strategy for this lesson.

Whole group discussion: Share findings in whole group.

2.3 PLANNING THE LESSON

Whole group discussion: Based on our discussion of student thinking about [topic], how might we go about introducing the topic to the students?

Facilitator reminds the team of their research themes.

Questions to consider:

- What kinds of questions and experiences do students have entering this lesson? How can these be sequenced or leveraged to bring students to where we want them to be when they leave?
- Who has access to participating in these activities? Who does not?
- How will students respond to the questions or activities we pose? How will we respond to them?
- What will make this lesson motivating and meaningful to students? What assumptions are we making about the students?

Week 3, Week 5, Week 7

Key Activities:
- 3.1 Preparation for the observation
- 3.2 Debrief of observation
- 3.3 Reflection on lesson

3.1 PREPARATION FOR THE OBSERVATION

Pre-meeting activity (to be done by facilitator)

Purpose of activity: Given the importance of having a live classroom at the center of the Lesson Study but also recognizing the constraint of one-hour per week meetings with the team, it is necessary that the teaching/observation phase is scaffolded to produce meaningful discussion and reflection.

Instructions: To prepare for the observation, the TA of study that week will tell facilitator what 5-10 minute clip was most salient to them during their teaching. The facilitator will cut the clip for view in the meeting.

Additionally, based on the clip, the facilitator will create an observation guide for Lesson Study participants to fill out when viewing the clip. It will resemble the following observation tool used by the Lesson Study Consortium:

Ex. of Student Development Theme: Students will be able to develop and value their own as well as their peers' perspectives

Ex. of Equity Theme: Students will exercise their scientific agency to ask questions, make observations, and make claims about the content and how it relates to their own lives

Ex. of Observation Guide:

Approximate Time	Learning Task	Point to note regarding student development theme	Point to note regarding equity theme	CDOP codes noted	Observer notes	Wonderings
Ex. 0:00-5:00	Students just finished a simulation of separating mixtures of compounds. TA is facilitating a discussion around the common conflation between distillation and evaporation.	How are students interacting, challenging, or building off of others' ideas?	What conditions or opportunities were created for students to relate the material to their lives?	Contextualizing--"Instructor asks students to connect ideas to conventional knowledge, border perspective, and personal experiences"	TA asked verbally and no student was speaking up. Then TA invited students to use chat generating more responses that the TA read out loud.	What strategies can facilitate peer-peer discussion rather than having it be filtered through the TA?

3.2 DEBRIEF OF OBSERVATION

In-meeting activity (20 minutes)

Purpose of activity: The debrief of the lesson gives team members the opportunity to reflect on their own conjectures about student thinking and deepen their understanding about teaching, learning, and instructional design.

Flow of discussion:

- GTA who taught the lesson comments on a) their reasoning for choosing this specific clip, b) their general impressions of how it went and how they felt, c) what they think went well, d) any difficulties or challenges they experienced in the lesson
- Watch the video clip (and re-watch, pause, rewind as needed)
- Participants fill out the observation sheet
- Team members share their observations and ground their comments in the observation and the evidence
    - Discussion about student development theme
    - Discussion about equity theme

Synthesizing our discussion:

- Summarize the key ideas and questions that emerged from the debriefing

3.3 REFLECTION ON LESSON

In-meeting activity (40 minutes)

Purpose of activity: By analyzing what we observed in the teaching clip, we can gather evidence to measure if the lesson achieved the goals we set. The evidence will also provide insight as to which aspects of the lesson plan need to be reconsidered.

Whole-group discussion prompt:
Question Set #1 (focused on the lesson recording) (Stepanek et al., 2007)

1. Describe your observations of student learning. Include details of what students said, did, and wrote/produced.
2. Were there any unanticipated student responses?
3. To what extent were the goals of the lesson achieved? What evidence from the teaching clip supports your claim?
4. Which instructional decisions (from our lesson plan or on-the-spot) might have contributed to helping students meet these goals?
5. What aspects of the goals were not achieved?
6. Which aspects of the lesson should be reconsidered based on this evidence?

Question Set #2 (focused on takeaways and future instruction)
1. What are some ideas that we want to takeaway for future instruction?
2. Based on our discussion, what specific ideas and strategies do we want to try and implement in our next lesson?

Final Week

Key Activities:
- F.1 Reflection on Lesson Study process

F.1 REFLECTION ON LESSON STUDY PROCESS

In-meeting activity (60 minutes)

Purpose of activity: This reflection will serve as a way to discuss and celebrate all that we have accomplished throughout the term. We will critically reflect on what aspects of lesson study were useful or challenging and how these instances and experiences shaped the way we think about teaching, learning, equity, and our students.

Instructions for individual activity: Create one Google slide in which you drop in images, quotes, and words that represent your experiences and accomplishments while participating in this lesson study cycle.

Whole group discussion: Let everyone have the opportunity to present their slide to the team.

Discussion prompts:

- What is useful or valuable about our lesson study work together?
- What other professional development opportunities have you participated in? How is lesson study similar or different to those opportunities?
- How has lesson study prompted you to think about the practice of teaching? About how students learn? About equity in the classroom? About instructional design?
- What was challenging about participating in lesson study?
- Is there anything else that you would like to discuss that we haven't yet touched on?

Appendix B: Weekly Reflection Template

The purpose of this weekly reflection is to allow you space to note down any thoughts or feelings that you experienced during or in response to this week's meeting. There are a few questions that will help me ensure that the group norms are being upheld. Your responses will be kept confidential and will not be shared with anyone. (All questions were optional)

Do you feel like the group norms were upheld in this week's meeting?
□ Yes
□ No

Would you like to expand on your previous answer?

Do you feel like you had ample opportunity to contribute during this week's meeting?
□ Yes
□ No

What can I do, as facilitator, to ensure this?

Reflection (modified from Barlow et al. 2020)

The following space is intended for you to openly and freely share your thoughts. Below are some guiding questions to help you organize your thoughts.

As you reflect on today's work, what is the biggest idea that is standing out to you? Write about the significance of this idea.

Following today's work, what questions do you have? Write a little bit about why you consider these to be important questions.

Did something change in your thinking today regarding TEACHING CHEMISTRY? If yes, what were you thinking before? What are you thinking now? What caused the change? If no, please describe the ideas or perspectives that were

Did something change in your thinking today regarding STUDENT LEARNING? If yes, what were you thinking before? What are you thinking now? What caused the change? If no, please describe the ideas or perspectives that were

Did something change in your thinking today regarding YOUR ROLE AS A TA? If yes, what were you thinking before? What are you thinking now? What caused the change? If no, please describe the ideas or perspectives that were

Appendix C: Post-Participation Interview Protocol

Thank you for participating in this interview. This interview will consist of three different parts. In the first part, I will ask you about your experience with Lesson Study. In the second part, I will ask you about your ideas on teaching and your role as a TA. In the final part, I will ask you about your teaching experiences and relationships with team members.

Your responses in this interview will be kept confidential. I will not retain any identifying features if we use your remarks for publication. The interview will be recorded. If you feel uncomfortable at any point during the interview, please let me know and I can stop at any time. Do you have any questions before we begin?

Part I: Participation in Lesson Study

1. If you were sharing your experience with lesson study to a friend, how would you describe it?

2. Do you feel like you benefited from this experience? If so how?

3. What were some challenges that you faced during your participation in lesson study?

4. Would you participate in this experience again? Why or why not? Would you recommend this opportunity to others? To whom and why?

5. What suggestions do you have to improve your experience?

6. (if applicable) How is lesson study similar to other professional development opportunities you have had? How are they different?

Follow-up questions:
a. What aspects from each professional development experience did you find most useful?
b. What aspects were not as useful?

I next want to go through each of the Lesson Study cycle stages.

1. Setting themes
   At the beginning of the course, we first planned the student development theme and the equity theme.
   a. How important did you see this stage? What did you benefit from it? What was challenging about it?
   b. How has this experience impacted or encouraged you to consider broader objectives or goals in your teaching?

2. Study
   In Lesson Study, we encountered the study phase. This is where we reflected on student conceptions of the topic or common alternative or partial understandings of topic content.

This is also where we reflected on when we first learned about this topic or have taught it in the past. This is also where we drew on others' teaching experiences, thinking about what students like, what teaching strategies were well-received, and strategies that were not well-received.

a. How important did you see this stage? What did you benefit from it? What was challenging about it?
b. How has this experience impacted or encouraged you to think about the ways students learn the content that you teach?
c. How has this experience impacted or encouraged you to study the way this content has been taught before?
d. How has this experience impacted or encouraged you to consider

3. Plan

In Lesson Study, we also encountered the planning phase. This is where we planned an activity together that we would all incorporate and implement with our students. The plan was really born from ideas and experiences from the team.

a. How important did you see this stage? What did you benefit from it? What was challenging about it?
b. How has this experience impacted or encouraged you to plan out the activities in section before you teach it?
    a. How has LS impacted or encouraged you to anticipate how students might respond and how you might respond to them?
c. How has this experience impacted or encouraged you to use different approaches to engage students?
d. How has this experience impacted or encouraged you to collaborate with other GTAs or course faculty (peers or faculty) about your teaching?

4. Teach

In Lesson Study, we did the "teaching" phase. This is where we watched a clip of one of us engaging with students in activities that we discussed prior.

a. How important did you see this stage? What did you benefit from it? What was challenging about it?
b. How has this experience impacted or encouraged you to collect or review student work or strategies to assess their understanding of a topic?
c. How has this experience impacted or encouraged you to consider or pay attention to classroom dynamics? (e.g. who is participating, how are they responding to each other, how they are feeling)

5. Reflect

Finally, in the Lesson Study, we reflected on how students learned the content, responded to our planned activities. We also reflected on how what we've learned would impact our future instruction.

a. How important did you see this stage? What did you benefit from it? What was challenging about it?
b. How has this experience impacted or encouraged you to reflect on your teaching practices?

c. How has this experience impacted or encouraged you to reflect on how students responded to your questions or prompts?
d. How has this experience impacted or encouraged you to reflect on how to revise or improve a lesson?
e. How has this experience impacted or encouraged you to reflect on if your lesson met the course objectives or departmental/university goals?
f. How has this experience impacted or encouraged you to reflect on how you collaborate with others on teaching?

Part II: Ideas on Teaching

1. What do you see as the purpose of teaching?

Follow-up questions:
a. How would you define teaching?
b. Can you give me some instructional strategies that exemplify effective teaching?
c. Why do you consider these effective teaching strategies? What goal do these achieve?
d. Has participation in lesson study impacted your perspective? In what ways?

2. What is the purpose of an instructor? What is the purpose of a TA?

Follow-up question:
a. Has participation in lesson study impacted your perspective? In what ways?

3. How has remote teaching impacted your views on teaching? On your students?

4. At this point in time, do you have a desire to teach as a future career? Why or why not?

Follow-up question:
a. Has participation in lesson study impacted this decision? In what ways?

Part III. Team Relationships

Course Instructor
1. How would you describe your relationship with [faculty course instructor]?

2. What was your relationship with [faculty course instructor] like prior to participating in Lesson Study?

3. How many times have you TA'ed for [faculty course instructor]?

4. How many times have you TA'ed in general?
a. How is the relationship that you had with [course faculty instructor] similar to previous relationships you've had with faculty members?
b. How is it different?

Fellow GTAs

1. How would you describe your relationship with the other GTAs in the Lesson study team?

2. What was your relationship with each member like prior to participating in Lesson Study?

3. How did you meet each member?

4. How many times have you TA'ed with each member?

Demographic Information

1. Preferred pseudonym and pronouns.

2. Graduate program currently enrolled in.

3. Racial and/or ethnic identity.

4. Gender identity

Appendix D: Five Teaching Perspectives Codebook

Codebook created based on Pratt & Smulders (2016)

	Transmission	Apprenticeship	Developmental	Nurturing	Social Reform
Emphasis in Teaching Model	• Teacher • Content	• Teacher • Content • Context	• Learners • Content	• Teacher • Learners	• Ideals
Goal of Teaching	• Efficiently and accurately deliver knowledge	• Socialize learners into community	• Help students develop complex or critical ways of thinking	• Help learners become confident and self-sufficient learners	• Transform society to align with certain principles and values
Role of Instructor	*Content expert* • Be knowledgeable in subject area • Answer questions • Specify what learners are expected to learn • Portray excitement and enthusiasm for content and field	*Role model* • Embody the knowledge, values, and practices of their community • Mentor, guide, and coach learners into the ways of the community	*Bridge between students and curriculum* • Reconstruct concepts in language and at levels of learners • Perturb learners' cognitive equilibrium	*Motivator* • Empathize with learners • Provide support and encouragement • Build learners' self-efficacy and independence • Establish trust with learners	*Social change maker* • Challenge ideas and motivate curiosity • Advocate for specific change in learners' perspectives

	Transmission	Apprenticeship	Developmental	Nurturing	Social Reform
Role of Learner	*Receiver of knowledge* • Organize and retrieve knowledge as conveyed by instructor	*Newcomer into community* • Participate and engage in authentic norms, language, and practices of the community	*Constructor of meaning* • Revise and refine their understanding to integrate new information	*Agent of their own learning* • Attribute their success to their own effort and ability	*Social change maker* • Use what they have learned to make an impact on society
Example of Teaching Strategies	• Provide advanced organizers • Frequent testing of understanding	• Model behaviors, practices, and language • Make implicit knowledge explicit for learners	• Assess learners' prior knowledge • Be aware of and attend to misconceptions • Use analogies, metaphors, and examples relevant to learners	• Address and respond to learners' motivations and needs • Provide frequent feedback • Celebrate learners' successes and address failures	• Situate assignments and projects that are relevant to and in the community • Share power and expertise with learners