Social Constructivism in Chemistry Peer Leaders and Organic Chemistry Students

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Social Constructivism in Chemistry Peer Leaders and Organic Chemistry Students

by

Aaron M. Clark

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy
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Keywords: education research, peer-led team learning, mentoring, approaches to learning

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Dedication

This dissertation is dedicated to all those students who struggle and feel alone. You are not alone. People care about you and want you to succeed. Believe in yourself and ask others for help. People are good, kind, and charitable. Surround yourself with people who will raise you up and once you are raised look around for those who you can raise.
**Acknowledgements**

“...Good timber does not grow with ease:  
The stronger wind, the stronger trees;  
The further sky, the greater length;  
The more the storm, the more the strength.  
By sun and cold, by rain and snow,  
In trees and men good timbers grow...”
- by Douglas Malloch

This is an excerpt from a poem entitled Good Timber. While I will quickly acknowledge that there are those who have much greater advisory in completing their daily lives as I have had in completing my degree I feel that setting up the background for why this means so much to me will help to show how much these acknowledgements actually mean to me and my success.

On May 24th, 2013 my life changed forever when I received a phone call from my older brother that our parents had died in a car accident. I had just completed my first year as a PhD student at the University of Oklahoma and was looking forward to getting some impressive progress done during the summer months. Nothing could prepare me for the emotional turmoil and upheaval that followed. I was lost and confused and at times completely directionless for the first time in my life. Later that summer one of my good friends in grad school took his life, Matlock I miss you and our long conversations about learning. Three months later my roommate, whom I had known since my undergrad years, and died suddenly from complications of Addison’s disease. Kurtis I am sorry I did not do more for you, but I am grateful for the chance I had to help you learn organic chemistry. My mental state at the end of this was terrible. The year following I could barely get out of bed and did not want to succeed. But I had so many good people in my life whose deeds got me through whether it was through kind words or actions or just prayers and good vibes sent my way. Trevor you were already one of my best friends before everything happened but afterwards your kindhearted Minnesota-ness got me through so many dark days, and you are my brother for life. There were so many people in Oklahoma that got me through these dark days, and I wish I could thank them all, but I just want any and all of them to know that if
they remember me to know that I remember them and their untold amounts of kindness. Dr. Cichewicz was my PhD advisor at the time, and I would just like to thank him profusely for his understanding and advice and even putting up with my foolish attempt to sound smart during my master’s defense. I thought I had done horribly but he kindly came out and proudly told me I had past and that all my work had yielded something that I could take away. He did however tell me that most students who get a master’s degree do not come back to get their PhD. I have had the dream of getting a PhD in chemistry since I was a teenager.

That stems from my chemistry high school teacher Mr. Roe. He made chemistry fun and made learning fun. Through him I found that teachers can be cool and smart but at the time it was not something I was interested in doing. That began to change in undergrad when I was given the chance to teach organic chemistry lab which I had grown to love in part because of my amazing TA Megan. She made learning fun as well and could make me think about topics more than I previously had and gave 110% effort for all her students. The teaching assistants worked with were amazing, but the students made my teaching life fulfilled. Calling me things such as the “half-blood prince” when I would “magically’ fix the reaction vial and save their experiment. I found that I had a passion and found joy in helping students learn organic chemistry. This passion and joy were only strengthened at Oklahoma and in the year when my life fell apart teachings is what saved me. It got me through everything and these students who came and loved me as their teaching assistant and who had no idea the hardships I was facing because when I was teaching them they let me forget how terrible life was at the time. I realized then that teaching is what I needed to do because even on the worse days I still could leave happy because I had given someone that light of learning and made them happy. The laboratory coordinator Kim was an amazing support and charitable person in this time, and I would like to thank her and let her know that she was right that eventually things turned out alright.
Life is meant to be an adventure and although I had my master’s degree I still longed to be happier and turned towards teaching at both the high school and adjunct professor level. I would like thank Diana West for giving me my first professional teaching job, even if it was teaching middle school science, which gave me a newfound respect for those poor middle school science teachers cause I lasted like a semester before I switched to high school science. Also Dr. Fern Caka at Utah Valley University while she was not the person who hired me, she has been amazingly supportive and was one of the reasons why I believed I could go back to graduate school after teaching at the adjunct level. Now as I am finishing up my dissertation, I look again kindly at the people who have helped me get through these years. First and foremost is the PhD advisor Dr. Jeffrey Raker that took a chance on a non-traditional graduate student who had no clue what chemistry education research really means and was/is so patient with everything. From the first data set he gave me and told me to code them and then just smiled when I came back into his office 30 minutes later and sheepishly asked what does coding mean? I could not have finished this without him and his support of me, my work, and my family. My wonderful fellow graduate student in my lab Rebecca, Caitlyn, Amber, Justin, Shalini, and Brandon. These people have become like family to me, mostly cause we fight and sacrifice like siblings. I have grown from all our interactions and from your constant feedback on my presentations and questions. For the laughs during game nights, classes, and everywhere in between Jacob, James, and Vanessa. For showing me how far someone can come Tawabar and Ying. For being examples of kindness and perseverance Guizella and Stephanie. And for teaching me how to be a better teaching assistant Ayesha. All these wonderful individuals have been such a major positive influence in my life.

Along with my advisor I would like to thank my committee members. Dr. Leahy was the first person I met here at USF and his openness and personality instantly won me over and made me feel welcome. His feedback and perspective have been extremely important in my learning process and how to make my work realistic for professors to implement. Dr. Scott Lewis has always had an open door for
me and has given me plenty of little moments of his time through all the years and I am so grateful for the advice and wisdom he has shown me and also helped me develop. Finally, my committee chair Dr. Luanna Prevost for saying yes to a student she had not met before who wanted her to be on his committee and who always gave great insight into my work and ideas. I originally thought the chemistry education was just about how to be the world’s best chemistry teacher and while that was not the goal of my dissertation work I still had interactions that have and will continue to help me be the world’s best chemistry teacher by standing on the shoulders of these giants. Dr. Raker again having such a passion for helping students make connections and see the usefulness of what they are learning. Dr. Fields who is the kindest organic chemistry instructor, she honestly cares too much but it was so inspiring to me to have someone like her be the instructor for the students I was teaching. Dr. Cruz even though I was never his teaching assistant through my research I became involved with his teaching and his students and was blown away at how well he instructs his classes. Finally Dr. Kulatunga for letting me work with her in instructing the peer leaders. This opportunity was so amazing to have the opportunity to work with students who were in turn helping other students was life changing. I will miss working with the peer leaders the most of all my assignments.

Finalizing my dissertation has taken almost a year due to the life upheaval events that existed in the year 2020. When I wrote the first draft of this in May my wife and I were struggling with the revelation that our unborn son has spinal bifida. Which could mean that he ends up paralyzed and brain damaged. This seems fitting in a way that my road to chemistry education which begins with tragedy might also end in the same way. However, this time I have experienced hardship and I am not saying that everything will be perfect, but I know that we can get through this. There are so many good people in this world who give charitably to others and I know that we as children of a loving Heavenly Father can get through the most difficult of trials if we rely on one the ones that He has put in our paths. Now
as finish writing this in January I know that tragically the surgery to attempt to save our child’s life did not work out and our son Daniel died. But I am still here, I am still finishing, and I still love what I do.

I would like to finish these acknowledges by recognizing the efforts of my family. First is my loving wife Jade who after being married for a few months moved across the country to start a new life and has been so patient with me and my work these past few years. Her family has become mine as well and I am so blessed to have the best in-laws who love and cherish me so much as they do. My own siblings have also helped me so much my older sister Amber for being the mom that I have needed these past 7 years. For my brother Adam for growing and maturing into the patriarch of our family. Austin for being the sibling that not only can I always joke with but also talk about deeper spiritual things as well. For Autumn for showing me how to overcome such advisory with the grit of someone 20 years her senior. For Anne for being so wise as to point out to her older brother that yeah our lives are hard but there are people out there who have gone through worse so what right do we have to complain and not pick ourselves up and do better.

Finally I know looking down from heaven are my parents Steve and Sue and while they cannot be here in the flesh I know that they still live and exist and can still feel pride in that I have not given up and I have accomplished the goals that I set with them over 16 years ago. I hope that my work helps people learn chemistry, but I hope that my story helps others know that you can do it. Life is meant to make us stronger so that we can be the best timber and construct the best world possible.
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Abstract

Social constructivist learning is a goal in many STEM programs. The goal of this dissertation is to shed light on what that pedagogy looks like in the context of organic chemistry courses and by peer leaders whose job is to implement this pedagogy with general chemistry and organic chemistry students. Learning is complex; the social constructivist ideas presented in this dissertation, however, are a straightforward means for promoting learning. Qualitative and quantitative methods used to explore social constructivist learning are outlined.

Three investigations were conducted: First, approaches to learning by students completing the first semester of a yearlong organic chemistry courses were studied. It was found that students who utilized a deep approach trended more positively with regards to examinations scores and persistence with the course. Second, the roles perceived to be enacted by peer leaders in the context of a flipped-peer-led team learning course were studied. Reflective journal entries suggest that mentoring is a common role for peer leaders despite that mentorship is not an explicit role that the peer leaders are trained and expected to fulfill. Finally, two scales were developed to measure the self-efficacy and beliefs about teaching and learning of peer leaders. These scales serve as a quick quantitative measure that can inform peer leader training.

Collectively, the results of these studies suggest that more attention should be focused on promoting and evaluating social constructivist learning in the context of general chemistry and organic chemistry courses. When the shared knowledge approach is adopted, studies suggest that more meaningful learning occurs. Tangible implications are offered for how this dissertation work can inform such adoption and reform efforts.
Chapter 1

Introduction

Organic chemistry courses have a reputation of being “weed out” courses (e.g., Lovecchio & Dundes, 2002; Grove & Bretz, 2010). Weston, Seymour, Koch, and Drake (2019) defined “weed out” as a course that
1) has a greater than 20% drop-fail-withdraw-incomplete rate, 2) is at the lower level, and
3) is required for a STEM degree. Among the lot of “weed out” courses, organic chemistry is unique in that it is a second-year course, whereas most other such courses are first-year courses (e.g., general chemistry, calculus). Estimates suggest that upwards of 50% of students switch out of STEM because of gateway chemistry courses (Weston, Seymour, Koch, & Drake, 2019).

Success in organic chemistry courses is dependent, in part, on study approaches used when learning the course material. Grove and Bretz (2012) found, for example, that approaches to learning, such as having flexibility to modify learning approaches, influenced how students approached studying in the course. Anderson and Bodner (2008) found that students who approached learning organic chemistry through memorization disproportionately struggled in the course.

Research shows that metrics used to predict general chemistry performance (e.g., SAT-Math) do not predict organic chemistry performance (Spencer, 1996; Pursell, 2007). Understanding how and why students struggle has been the goal of many studies in organic chemistry courses (e.g., Cooper & Stowe, 2018; Anderson & Bodner, 2008; Grove & Bretz, 2010). For example, studies have focused on difficulties learning particular concepts and skills (e.g., Galloway, Leung, & Flynn, 2018; McClary, & Talanquer, 2011), revising the organic chemistry curriculum and the broader chemistry curriculum (e.g., Flynn, & Ogilvie, 2015; Cooper, Stowe, Crandell, & Klymkowsky, 2019), and developing impactful learning experiences for targeted concepts (e.g., Dood, Fields, Cruz-Ramírez de Arellano, & Raker, 2019; Grove,
Cooper, & Rush, 2012). Missing from the organic chemistry education research literature is an understanding of how students construct their knowledge and skills outside the classroom (e.g., studying on their own in the library or through group study sessions). In particular, do students spontaneously engage in study approaches that are indicative of learning? For instance, using deep learning approaches that extend beyond memorization (Marton & Saljo, 1976) or through interaction with peers and others when studying (Vygotsky 1978).

Social constructivism is a framework that sheds light on how studying organic chemistry could be more effective. Social constructivism is a theory that asserts that knowledge is created in social situations, i.e. that greater understanding is developed when learning with others then could be achieved individually (Piaget & Elkind, 1968; Vygotsky, 1978). Social constructivism, thus, has active and engaging learning at its root. Active learning is having students take a more prominent role in their education by not sitting passively listening to an expert recite content (Freeman et al., 2014); for example, posing clicker questions during lecture in which students work by themselves or with peers to solve a recently presented concept (e.g., MacArthur & Jones, 2008). Clicker questions could lead to meaningful discussion between peers as they pool their respective ideas and thoughts together to solve the problem. Alternatively, clicker questions could also lead to students leeching off the one student who quickly understood the concept and simply replicating answers with no construction of knowledge occurring (James, 2006); James pointed out that by focusing on formative assessment with clickers instead of summative assessment lowers the incentive for this to happen.

Students should actively engage with their peers outside of the classroom in an effort to better understand course material (Christian & Talanquer, 2012). In addition, students should approach their studies from a deep approach, seeking to understand the course material beyond a superficial level (Bunce et al., 2017). Thus, when combined, collaborative and deep approaches are hypothesized to be foundational to creating well-formed understandings of organic chemistry. Having such understandings,
for example, of what is happening in a reaction mechanism and why reactions occur can build confidence and success (e.g. Grove, Cooper, & Rush, 2012). This is contrasted with surface-level and memorization-based approaches used by students in isolation that could lead to underdeveloped understandings of course content. Based on the assumption that students utilizing a deep collaborative learning is ideal for overarching success in organic chemistry, a finding that students do not engage in such approaches would suggest the ideal and meaningful learning is not occurring.

Social constructivism informs both classroom pedagogies as well as approaches to studying, i.e. when necessary and sustained learning occurs. Social constructivist learning is the basis for the peer-led team learning (PLTL) program, a pedagogy emerging from the work of chemical education, and other active learning pedagogies (Gosser et al., 1996). PLTL is a pedagogical strategy that pairs a peer leader with small groups of students for the primary purpose of completing an instructional activity (e.g., end-of-the-chapter problems or guided-inquiry worksheets; Gosser et al., 1996). Peer leading sessions are typically held once per week for the duration of a term in place of recitation sections but can be implemented as supplemental extra help sessions as well. In the PLTL program, students engage with peers under the guidance of a more advanced peer, i.e. a peer leader, who facilitates collaborative learning through completion of preassigned problems. Courses using PLTL have been shown to be associated with increases in student achievement (e.g., Drane, Smith, Light, Pinto, & Swarat, 2005; Hockings, DeAngelis, & Frey, 2008; Mitchell, Ippolito, & Lewis, 2012; Stewart, Amar, & Bruce, 2007; Tenney & Houck, 2003). Work done by Brown, Sawyer, Frey, Luesse, and Gealy (2010) found that due to peer leaders’ primary interaction being either instructor-based or facilitated-based caused disparity among the peer-group experiences; peer leaders using more instructor-based approaches lead to fewer collaborative discussions and less chemistry understanding. Note that Brown et al. (2010) collected their findings after the semester had ended and did not have the ability to address and correct the misguided peer leaders. A quick survey that peer leaders could take on teaching beliefs and confidence enacting
the PLTL pedagogies is a possible means to address such issues. The survey results would help instructors address issues by meeting with the peer leaders one on one to discuss their survey results.

Mentoring is a noted byproduct of the PLTL experience (Wilson & Varma-Nelson 2016). Báez-Galib, Colón-Cruz, Resto, and Rubin (2005) purposefully incorporated a mentoring aspect into their PLTL program; including mentorship training in peer leader training was associated with a decrease from ~45% failure rate to 22% for participants in the program. Students in the Báez-Galib et al. study specifically mentioned that they “learned valued of not quitting” and that the peer leaders “helped maintain and improve my study habits.” Unfortunately, most reports of peer leader training programs and implementation of PLTL lack a mentoring component. Such mentoring relationships and related behaviors/interactions are non-spontaneous within the PLTL context: For example, Johnson, Robbins, and Loui (2015) stated that their peer leaders did not mention making personal connections with students. It should be noted that the PLTL leaders in the Johnson et al. study struggled to engage students towards a more conceptual understanding and articulate why conceptual understanding of course material is beneficial. There remains an opportunity to better understand how peer leaders characterize their role in facilitating learning and building relationship with their students; by extension, there remains an opportunity to optimize peer leader training programs to maximize benefit for the peer leaders and the students they serve.

Importance of This Dissertation Work

The work presented in this dissertation champions deep and collaborative learning rooted in social constructivism and seeks to uncover tangible implications for how the teaching and learning of organic chemistry can be improved. This work furthers the research literature presented in the preceding section by exploring the study approaches that naturally occur in the context of the first semester of a yearlong postsecondary organic chemistry course (Chapter 3), considering the perceived roles of peer leaders facilitating learning in the first semester of a yearlong postsecondary organic
chemistry course (Chapter 4), and developing an instrument to measure peer leader’s self-efficacy and beliefs about learning (Chapter 5).

The first semester course of the yearlong postsecondary organic chemistry courses presents an interesting context for studying learning. There is a known paradox that students who enter the course with strong science backgrounds and excellent grades in general chemistry (i.e., the preceding postsecondary chemistry courses), thus predicted to do well in organic chemistry based on prior performance, can falter in the course (Lovecchio & Dundes, 2002). This is on top of the notoriety that organic chemistry has for being a course in which high drop-failure-withdrawal rates are observed (Weston et al., 2019). The hypothesis is that how students in the course approach their studying will have a large impact on their success in the courses; this hypothesis is supported by work that suggests such students primarily take a memorization approach to studying (Grove & Bretz, 2012; Novak, 2002). However, learning when considered from a social constructivist framework, suggests other approaches and behaviors that are indicative to learning. This is further emphasized in the specific context that this dissertation research was carried out at, in that students (i.e., potential study participants) enrolling the target organic chemistry course will have experienced PLTL in their general chemistry courses. If strategies that students are using to study for the organic chemistry course can be identified, there is the possibility of designing classroom experiences and other interventions to promote better, more theoretically sound study approaches that lead to greater success in the target course. Such as getting students to make connections with their peers to learn and discuss together during their personal study time.

Peer led team learning is a program that emphasizes making connections between individuals. The process is designed so that groups of students have access to each other and a near-peer. This idea of having someone more experienced than you be available to help guide you through problems is at its core the same concept that universities use in peer mentoring programs (e.g. Becvar, Dreyfuss, &
Mentoring of students by peer leaders has been observed in the context of PLTL (Gosser et al., 2001); however, the extent to which mentoring occurs nor mentorship training for peer leaders has not been documented in the literature. This gap is noteworthy due to the research on mentoring showing that formalized and explicit mentorship training has an effect on achievement in postsecondary courses and persistence in postsecondary degree programs (e.g. Becvar, Dreyfuss, & Dickson, 2008; Colvin & Ashman 2010). A primary goal of PLTL is to increase retention within classrooms of which peer mentorship programs outside of PLTL have been shown to be associated with increased retention (e.g., Damkaci, Braun, & Gublo, 2017). Peer leading sessions are an ideal context for mentorship, as described by Buntinga & Williams (2017), namely that meaningful engagement in a learning environment is advantageous for peer mentorship. If peer leaders could be used as mentors in addition to facilitators of learning, PLTL programs could promote better, more personal experiences that lead to greater success for individuals in the course.

Peer led team learning programs are dependent on the individuals running the programs, in particular the peer leaders themselves. While these individuals are qualified, and receive initial and continuing training, there is not an instrument that can quickly inform instructors of peer leaders of the teaching and learning beliefs and teaching self-efficacy of peer instructors. Such an instrument could serve two purposes: First administration of the instrument in a pre/post manner could provide evaluative data on the combined impact of any professional development experiences (i.e., weekly peer leader training in our study) and experiences implementing peer-supported instruction (i.e., enacting PLTL experiences). Second, results could inform trainers of peer leaders and learning assistants as to initial confidence levels and teaching beliefs prior to professional development experiences. Administration of the instrument combined with a whole group discussion could serve to further prepare the near peers for their learning facilitator roles.
Outline of Chapters

Following this introductory chapter, five additional chapters are presented. Chapter 2 describes the methods and methodologies used to collect and analyze the data collected in the studies reported in the three study Chapters that follow. These methods elaborate on the qualitative and quantitative methods reported, especially for Chapter 4 and Chapter 5 which, as written, are targeted towards practitioner audiences. Next, Chapter 3, Chapter 4, and Chapter 5 (the study Chapters) include a description of the motivation, research questions, methods, data, and findings for each study. Notations are made at the beginning of each chapter as to whether and where each study has been published in a peer-review journal. Finally, Chapter 6 is a summary of the dissertation research including overarching implications for the reported studies.

The first project (see Chapter 3) involved students’ differing approaches in a first semester organic chemistry class. The study strategies of sixteen postsecondary students were explored through in-depth interviews conducted at two moments across the first semester of a yearlong course in organic chemistry. Two theoretical frameworks that operationalize social constructivism and active approaches to learning were utilized to analyze semi-structured interviews: These theories frame student approaches as surface or deep (Marton & Saljo, 1976) and individual or collaborative (Tang, 1993). The application of two complementary frameworks allowed for grouping students into four categories: surface-individual, surface-collaborative, deep-individual, and deep-collaborative. Through a holistic analysis of the data, findings suggest an interplay between surface/deep and individual/collaborative approaches. Data suggest that students often do not have a good understanding of what collaborative-deep learning entails. Instructors, thus, have an opportunity and a responsibility to model more social constructivist and deeper learning strategies to promote learning and performance in organic chemistry.

The second project (Chapter 4) focused on analyzing the responses of 52 organic chemistry peer leaders to a prompt about their perceived role end the end of a semester of working as a peer leader.
The prompt asked peer leaders to describe their relationship with their students by choosing a role that best described that relationship and to provide an example of how they filled that role during the term. Responses were coded and analyzed for patterns. Results suggest that when peer leaders describe their relationship with students, some express themselves as teachers, others consider themselves guides or facilitators, and some view their role as a mentor. The mentor role is an understudied relationship among peer leaders and their students (c.f., Wilson & Varma-Nelson 2016). Mentoring, though, was reported by a large majority of peer leaders (n = 22). Peer leaders who identified as mentors in the study wrote that they valued building and having a mentor-protégé relationship with their students. From a peer leader trainer perspective this is an unexpected relationship, as the main function of a peer leader as recommended when implementing PLTL is facilitator or guide of learning. This study addresses the gap in understanding peer leaders’ experiences and the impact of implementing PLTL on peer leaders.

The final project (see Chapter 5) continued the process of looking at what characteristics and values peer leaders have before and after their experience in peer leading. The scales for self-efficacy and teaching beliefs were developed based on previous instruments that measure teaching beliefs and self-efficacy of graduate teaching assistants (i.e., Wheeler, Maeng, Chiu, & Bell, 2017; Navarro, 2005; DeChenne, Enochs, & Needham, 2012). Construct and face validity, measurement reliability, and factor structure were determined using a population of near-peer facilitators working in general chemistry courses using PLTL pedagogies. Results of the study suggest that the scales produce valid and reliable data. Additionally, both teaching self-efficacy and beliefs increased between pre/post administrations with small to medium effect sizes. The developed scales provide an efficient means to evaluate peer-supported pedagogies. In particular, results can be used as discussion points when training near-peer facilitators. Also, data could be used to identify benefits of PLTL and similar programs.

A summary of the overarching conclusions and implications drawn from these three studies are presented in Chapter 6. Advocation is made for the incorporation of deep-collaborative learning into the
approaches of chemistry students as necessary work to improve student outcomes. Such work falls on instructors to demonstrate what these more effective approaches look like and how best to implement those approaches. There is an opportunity for educators and researchers to reflect on current practices and offer opportunities for growth towards more engaging and meaningful learning experiences in chemistry courses. This extends to all ‘instructional’ personnel including faculty members, peer leaders, graduate teaching assistants, etc. Peer leaders and chemistry students can benefit from interaction with peers through learning, mentoring, and socialization. Additionally, instructors implementing PLTL need to take a more active role in evaluating and monitoring peer leaders, giving peer leaders feedback essential to their growth as learners and educators. Quick assessments of peer leader’s self-efficacy and teaching beliefs provide a critical starting point for professional development discussions that will hopefully have a positive impact on the learning facilitated by those peer leaders.

Ultimately, the approaches faculty and students use to facilitate learning have a measurable impact on student success in chemistry courses. The work presented in this dissertation seeks to further understand the learning experiences of organic chemistry students and peer leaders facilitating PLTL pedagogies; additionally, the work seeks to identify the next steps for related research and means for improving teaching practices. Social constructivist-based approaches to learning have the possibly of improving outcomes such that organic chemistry, and other chemistry courses, can be removed from the “weed out” list.

References


Chapter 2

Qualitative and Quantitative Methodologies

The work presented in this dissertation used qualitative and quantitative methods to collect and analyze data. Specifically, qualitative methods were used in Chapter 3 and Chapter 4, and quantitative methods were used in Chapter 5. This chapter will detail those methods. Specifically, these aspects of qualitative research will be described: methodological frameworks, data collection, sampling and data saturation, and trustworthiness. For quantitative methods, these aspects will be described: factor analysis (both exploratory and confirmatory), scale scoring, and the Wilcoxon-Sign test. All research was conducted at a large, public, doctorate-granting institution in the Southeastern United States in organic chemistry courses, general chemistry courses, and in some courses implementing peer-led team learning (PLTL) pedagogies.

Instructional Context

Data for this work was collected from gateway chemistry courses, both organic chemistry courses (Chapter 3 and Chapter 4) and general chemistry courses (Chapter 5). Data we also collected from peer-led team learning training courses in conjunction with large lecture-based courses (Chapter 4 and Chapter 5).

Yearlong Postsecondary Organic Chemistry Course.

Participants for the Chapter 3 study were recruited from the first semester of a yearlong postsecondary organic chemistry course at a large, public, doctorate-granting institution in the Southeastern United States. Every participant had previously completed the second half of a yearlong general chemistry course sequence earning a passing grade; this general chemistry course has a PLTL component (c.f., Robert, Lewis, Oueini, & Mapugay, 2016). This ensured that every student interviewed
would have had at least one semester of social constructivist-based learning in a chemistry course. Each section of the organic chemistry course from which participants were recruited met for two 75-minute class periods each week and was complemented by a weekly 50-minute recitation led by a teaching assistant. Students were evaluated in part by four in-term, open-ended exams, and one multiple-choice final exam. The instructor of the course “dropped” the students’ lowest in-term exam grade.

**Peer-led Team Learning.**

For Chapter 4 and Chapter 5, participants were students enrolled in a peer-led teaching course unique to the institution were participants could receive three credits of upper-level science credit for completing the course. All peer leaders at the institutional context are required to meet for a weekly training session before they interacted with students for their respective course. All data were collected at a large, public, doctorate-granting institution in the Southeastern United States. At the institution, all sections of the first-semester general chemistry course experience PLTL within a required recitation session. In the second-semester general chemistry course, students self-select into sections that do or do not use PLTL in the classroom (c.f., Robert, Lewis, Oueini, & Mapugay, 2016). For three semesters, including the timeframe in which the Chapter 4 study was conducted, the first-semester organic chemistry course also had the option for students to self-select into a course with PLTL sessions. For Chapter 4, peer leader participants were working within the first semester PLTL organic chemistry course. For Chapter 5, peer leader participants were working within the first and second semester PLTL general chemistry courses.

**Qualitative Methods**

Qualitative methods are a range of techniques that allow for the collection and analysis of non-numerical data usually descriptive in nature (Patton, 2015). These methods focus on collecting non-numerical responses from participants that allow for rich, deep analysis. Interviews, focus groups, or text analysis are common data ways to generate qualitative data. Data collection methods are generally
guided by frameworks either theoretical or methodological. Theoretical frameworks are a theory base that guide the researchers through data generation and analysis and provide focus for the research team (Wolcott, 1995). Methodological frameworks are more focused on how interviews are conducted, artifacts are reviewed, and how analysis is conducted (McMeekin, Wu, Germen, & Briggs, 2020). Data are analyzed through theoretical frameworks, guiding what information has substance and worth. In addition, qualitative methods are constrained by sampling, data saturation, and trustworthiness.

Sampling is the process used to identify and select observations from a larger population. Data saturation refers to when no new information is found in data analysis and indicates that data collection may end. Trustworthiness refers to the steps taken, and checks made by researchers to ensure an honest representation of the data and results.

In the remainder of this section, each of these aspects of qualitative research (i.e., theoretical frameworks, methodological frameworks, sampling, data saturation, and trustworthiness) will be further described with commentary on how each applies to the work reported in Chapter 3 and Chapter 4 of this dissertation.

**Theoretical Frameworks**

Theoretical frameworks are the basis for how data are analyzed and can inform how data are collected (Wolcott, 1995). Incorporating a theoretical framework into the design of a study is suggested so that the research project is conducted with a more focused and scientific approach (Henstrand, 2006). Having a set theoretical framework allows for the researcher to begin data collection and analysis with a foundation from which to build, instead of attempting to create or allow something to emerge in the context of the study. It should be noted that there are examples of studies where no set framework is used; such studies are referred to as grounded theory (Glaser & Strauss, 2017). The studies reported herein, however, are not grounded theory studies and are built on preexisting theories.
In Chapter 3, the theoretical frameworks of approaches to learning (Marton & Saljo, 1976), social constructivism (Piaget & Elkind, 1968; Vygotsky, 1978), and collaborative learning (Tang, 1993) are used. In Chapter 4, the theoretical framework of mentor/protégé relations (Kram, 1983) is used. Each are described further:

**Approaches to Learning and Social Constructivism.**

Theories on deep-surface approaches to learning (Marton & Saljo, 1976) and social constructivism (Piaget & Elkind, 1968; Vygotsky, 1978) were used in the study described in Chapter 3. In addition to use of each theoretical framework individually, the two frameworks were considered together, as described below, to provide a more nuanced analysis.

Marton and Saljo (1978) identified two key approaches to learning: deep and surface. They found that students approaching an academic task from with a deep approach made connections between ideas. Whereas students approaching an academic task from a surface approach focused more on blunt memorization techniques. Brown and Chin (2002) further operationalized the deep-surface approaches framework to include depth of answers, metacognition, and persistence. In Chapter 3, the self-reported learning approaches of organic chemistry students were characterized using Brown and Chin’s operationalization of Marton and Saljo’s deep-surface framework.

Social constructivism asserts that knowledge construction takes place in the collective minds of a group, and that knowledge is rarely created out of nothing but from many parts that form the whole of knowledge (Vygotsky, 1978). Taking a more specific approach to social constructivism, work done by Tang (1993) showed that students who worked collaboratively on an assignment utilized higher-level cognitive strategies than students who worked individually. Collaborative groups were spontaneously formed, student-centered, and students had positive perceptions of the experience. Students in the collaborative category mentioned finding answers through working with peers and having the ability to both be taught and teach others to strengthen their understanding of the material (Tang, 1993).
Students in the individual category mentioned not wanting to engage with other students citing lack of preparedness, anxiety, and scheduling conflicts (Tang, 1993). In Chapter 3, groups formed and reported by participants were spontaneously formed groups; thus, Tang’s perspective fits well with the study.

By combining these two frameworks, four possible combinations were created: surface-individual, surface-collaborative, deep-individual, and deep collaborative. These frameworks fit well together based on the theory that collaborative learning is effective because in principle it encourages individuals to make connections and give meaningful explanations to their peers. Some individuals may be able to generate deep learning by themselves without the need for others, these would be the students who can generally succeed in any course no matter the pedagogy employed. The goal by combining these two frameworks was to see if individual-surface learning always leads to failure or if collaborative-deep learning always leads to success.

*Mentor-Protégé Relationship.*

The theoretical framework used for the study in Chapter 4 is the mentor-protégé relationship (Kram, 1983). Kram argued that a mentoring relationship serves two functions: The first function is that the mentor gives advice or guidance about development behaviors that can lead to success in the protégé’s choose field. The second function is personal support; such support can come in the form of socialization or emotional support, known collectively as psychosocial support (Kram, 1983; Bozeman & Feeney, 2007; Eby, 1997). In Chapter 4, the examination of written responses (N=52) from peer leaders showed that a large minority selected mentor (n=21) as their perceived role. Kram’s definition was operationalized for the Chapter 4 study by focusing on advice and psychosocial support, as these two aspects were apparent in the limited data collected.

**Methodological Framework**

Methodological frameworks are a means to guide qualitative researchers through the data collection, analysis, and sometimes dissemination processes (McMeekin, Wu, Germeni, & Briggs, 2020).
In Chapter 3, phenomenography (Marton, 1986) was used to examine approaches to learning within our study constraints. In Chapter 4, thematic analysis (Guest, MacQueen, & Namey et al., 2012) was used to reduce and summarize data into manageable themes.

**Phenomenography.**

Phenomenography is the process in which the characterization of ways of experiencing a phenomenon has an irreducible solution (Marton, 1986). In a phenomenographic study, a researcher seeks to understand the variation of each individual’s experience and conception of a shared experience or phenomenon (Marton); for example, in what ways do students change their study approaches after receiving a lower-than-expected grade on an examination? Through the research process, themes (or ways of experiencing the phenomenon) emerge from the data until there are no new ways of characterization (Marton). The phenomenon studied in Chapter 3 is study approaches used by students taking an organic chemistry course.

**Thematic Analysis.**

Thematic analysis is a methodological framework used to identify themes that emerge from qualitative data (Guest, MacQueen, & Namey et al., 2012), thus an analytical tool to reduce and summarize data. Boyatzis (1998) outlined five purposes for utilizing thematic analysis: thematic analysis provides a means (1) of seeing, (2) of finding relationships, (3) of analyzing, (4) of systematically observing a case, and (5) of quantifying data. Data are read several times to get a sense of overarching themes. Then, open coding is applied; open coding is the technique used when there are no predetermined codes guiding analysis (Mills, Durepos, & Wiebe, 2010). The constant-comparative technique (Strauss & Corbin, 1990) follows open coding and involves looking back through all previous codes when a new theme is discovered; the review process, i.e. the comparative process, is used to verify that the theme was indeed new and should be included in the analysis (Charmaz & Belgrave, 2012). Thematic analysis was used in Chapter 4 to analyze responses by peer leaders to a reflection
journal prompt. In Chapter 4, codes and themes were further organized by the role identified by the peer leader; this further categorization provided a more refined understanding of the data and identified themes.

**Data Collection**

There is an array of methods for the collection of data in qualitative research. Methods range from observations, textual or visual analysis (e.g. from written responses to questions), and interviews (individual or group). In Chapter 3, semi-structured individual interviews were used to gather data from participants. Also in Chapter 3, think-aloud interviews were used to observe the problem-solving thought process of the participants. In Chapter 4, data were from paragraph length written responses from an open-ended journal prompt.

**Semi-Structured Interviews.**

The intention of qualitative interviews is to understand, explain, and explore experiences, opinions, and behavior of individuals or to make predictions about the population at large (Patton, 2015). The interviewer is the tool to help a participant reflect on their experiences. The key to the interview process is the soliciting of situations, feelings, events, or memories that the interviewee has experienced. Data collection quality is interviewer dependent (Patton, 2015). Responsibility falls on the researcher to prepare questions that result in meaningful responses (Dickson-Swift, James, Kippen, & Liamputtong, 2007). Interview questions can be designed to be open-ended, clear, and aimed at eliciting responses that reflect the interviewees’ experiences (Patton, 2002), while being mindful of and keeping the confidence of the participants (Dickson-Swift, James, Kippen, & Liamputtong, 2007). Rapport gained through building trust is an important step to obtaining quality responses from interviewees (Webb, 1984). This is important because these varying experiences should lead to different follow-up questions being asked to each participant. Such questions are more personalized in order to capture the participant’s experience more fully.
Semi-structured interviews were a key data source in the study described in Chapter 3. Interview questions focused on asking “how do you study for organic chemistry?” and “how do you study for your other courses?” Some students had differing experiences; therefore, the semi-structured protocol allowed for follow-up questions that expounded on a participant’s experiences. Follow-up questions such as, “describe the interactions that are happening when you are with your friends studying” and “why do you prefer to study alone?” These questions help to generate more holistic and deep data from the participants but differed from participant to participant.

*Think Aloud Interviews.*

Think aloud interviews have participants work through problem tasks and articulate their process or approach while working on the problems (Ericsson & Simon, 1984). Think aloud interviews routinely appear in organic chemistry education research (e.g., Bhattacharyya & Bodner 2005; Rushton, Hardy, Gwaltney, & Lewis, 2008). This data collection methodology allows for a real time look at the thought process of students. Researchers have used think aloud interviews to identify otherwise elusive rationale for why students respond to problems the way that they do; for example, Cooper, Kouyoumdjian, and Underwood, (2016) asked questions about the reaction of hydrochloric acid (HCl) with water (H₂O). Thus, think aloud interviews provide a different type of data compared to semi-structured interviews. Both techniques give different yet complementary insights when purposively constructed. For example, Stephenson, Duffy, Day, Padilla, Herrington, Cooper, and Carmel (2020) combined the techniques to determining readability and clarity of prompts when examining responses that provide evidence of students’ ability to construct a coherent scientific argument.

Think aloud interviews provided a second key data source (along with semi-structured interviews) for the study described in Chapter 3. In particular, think aloud interviews were used to ascertain if students could correctly predict the electron pushing formulation and products formed for acid–base, Sₙ₁, and Sₙ₂ reactions. Interview notes were made while watching the participants complete
these problems including verbal and body language cues. For example, participants expressed nervousness on working the problems and many voiced concerns at the start of the interview about making them do problems. Informed by Chin and Brown’s (2000) approaches to learning framework, cues about determination while solving the problems were noted. For example, level of determination is often presented in concurrence with verbal comments (e.g., “I don’t know”); body language observed by the interviewer helped to confirm that the interviewee was confused and uncomfortable with solving the problems.

**Document Analysis of Written Responses.**

In Chapter 4, data was from a population-based sample (Lavrakas, 2008). All peer leaders ($n = 51$) for the target organic chemistry course were given an assignment for course credit. Thus, convenience sampling allowed for our question to be administered to all peer leaders in the course. The use of documents, such as journal entries, is an important side of qualitative research. It allows for insight into human thoughts and feelings at a much larger scale than could be afforded from qualitative interviews (Patton, 2002) The open-ended journal entry responses provided a window for researchers to understand the world as seen by the respondents. While the respondents were constrained to nine “role” options, open-ended descriptions of how the selected role suggested the data collection process resulted in rich, descriptive data for analysis.

**Sampling and Data Saturation**

Sampling in qualitative research studies is aimed at gaining insight into a phenomenon, and not empirical generalization from a sample to a population (Patton, 2002). There exists no catch all rules for sample size for qualitative research studies, but guidelines that suggest a balance between resources and population (Daniel, 2011). This is in part due to the naturalistic inquiry that qualitative research tends to lend itself to. While the design of the study will often require an initial focus, plans for observations, and initial guiding interview questions, these plans do not always entail the finalization of
sampling schemes (Patton, 2002). The naturalistic and inductive nature of the inquiry makes it both impossible and inappropriate to specify operational variables such as number of individuals to be examined at the outset of investigation (Patton, 2002). To summarize, Patton states that, “a naturalistic design unfolds or emerges as fieldwork unfolds” (p. 44).

Purposeful sampling was used in the qualitative studies reported in Chapter 3; participants were selected based on previous exposure to social constructivist-based pedagogies (i.e., PLTL in their general chemistry coursework). All students who met the criteria of exposure were then emailed, and the first 16 respondents were chosen to participate; thus the sample was in part based on self-selection (Lavrakas, 2008). Sixteen participants, it should be noted, were the maximum number of participants allowable due to availability of limited compensation resources (i.e., university bookstore gift certificates). While this seems arbitrary the number, 16 aligns well with suggested methods for estimating sample sizes for phenomenographic studies (Trigwell, 2006; Trem, 2017). Trigwell argued that the ideal range participants in a phenomenographic study would be between 10 and 30. Work done by Trem in analyzing phenomenographic studies supports Trigwell’s conclusion; Trem adds that erring on the lower end of that range is sufficient if variation is found.

Saturation achievement was based on the claims of Corbin and Strauss (2008), who argued that saturation is more than the discovery of ‘no new codes’ as new data are examined. Data saturation in qualitative studies, such as phenomenography, is the point when by collecting more data, no new information or enhanced understanding is added to the study (Daniel, 2011). Corbin and Strauss (2008) argued that when using predetermined sample size (as in Chapter 3), a softer version of saturation could be to examine how prevalent the codes are across such data. Morse (2000) stated that “the quality of the data and the number of interviews per participant determine the amount of usable data obtained” (p. 4). In Chapter 3, two one-hour interviews with each participant resulted in an abundance of data.
In Chapter 4, peer leaders completed a reflection journal entry at the conclusion of being a peer leader. This reflection journal asked the peer leaders to “Choose ONE (1) of the following roles you feel best describes you in relationship to the students you worked with this semester: teacher, facilitator, instructor, guide, mentor, promoter, coach, assistant, advisor. Describe one concrete example of your interaction with a student(s) that best illustrates you serving in that role.” Definitions for the roles were not supplied, allowing respondents to self-interpret. The role options mirror those enacted by teachers in environments adopting a constructivist paradigm (e.g., Gergen, 1995; Mayer, 1996) and in studies of roles espoused by peers in similar situations and contexts (e.g., Colvin & Ashman 2010). Peer leaders were required to complete the reflection journal in order to receive credit for the course, as such all 52 peer leaders submitted a response. Similarly to Chapter 3, the sample size was determined by the resources available. As such a softer version of saturation was used to examine how prevalent the codes are across such data (Corbin & Strauss, 2008).

**Triangulation**

Triangulation is the combination of at least two or more theoretical perspectives, methodological approaches, data sources, investigators, or data analysis methods (Thurmond, 2001). Triangulation is considered parallel to validation (Flick, 2018) in quantitative studies.

In Chapter 3, data were collected from multiple sources and conclusions were based on how participants vocalized their thought process during the think aloud and how it compared with their level of collaborative learning. Data were triangulated by comparing self-reported approaches to studying, examination scores, and responses to the cognitive tasks during both interviews. Furthermore, lecture periods were attended for the entirety of the course to understand methods employed by the course instructor, to identify strategies the instructor offered for how to best study, and to verify that the items asked in the interviews were not previously discussed but were similar in context to the material presented. These observations and field notes triangulate and complement the interview data by giving
context to our conclusions that a passionate instructor was telling the students how to approach studying and yet there was a lack of explaining how to execute said approaches.

In Chapter 4, data were mined from open-ended journal entry responses and were collected before project design was completely realized which limited the methodological approaches available, since follow up questioning or observations were not possible. However the data was a combination of both a one-word role selection followed by a brief example or reasoning. This is a simplistic version of triangulation, as it allowed us to answer the question how the perceived role of the peer leader translates into their interactions with students. The data were collected over three different semesters which gives some validation in that the data were not from a single point or group.

**Trustworthiness**

Following established guidelines, both studies (Chapter 3 and Chapter 4) addressed trustworthiness in multiple ways. Trustworthiness in qualitative research refers to the accuracy of a research study, data, and findings (Lincoln & Guba, 1985). With qualitative studies, the researcher is the instrument; therefore, certain criteria exist to help ascertain that the conclusions drawn from the data are trustworthy and exhibit trustworthiness (Lincoln & Guba, 1985). Trustworthiness is how much value an individual can place in qualitative data and associated analysis and interpretation.

Lincoln and Guba (1985) suggested “credibility as an analog to internal validity, transferability as an analog to external validity, dependability as an analog to reliability, and confirmability as an analog to objectivity” (p. 301). Each of these elements provides a different dimension to trustworthiness claims.

Credibility refers to the amount of confidence in the ‘truth’ of the data, and how accurately the data were interpreted. Dependability refers to the nature of data interpretation being consistent for the researcher; thus, reading the data once and drawing conclusions is insufficient for establishing dependability. Coding, reviewing those codes, and reexamining the data should happen repeatedly allowing for a thorough understanding of the breath of the data.
Confirmability: data must be reviewed by outside sources to help eliminate potential biases or limited explanations by the researcher. For example, codes could be brought to a research group meeting and debated on appropriate code assignment and conceptualization. Peer debriefing through presentations to fellow researchers (e.g., through group meetings, workshops, and conferences) further establishes the trustworthiness of coding and data interpretations (Spall, 1998). Peer debriefing is done through discussing themes and roles with colleagues who are not connected with the project but with some familiar with the qualitative coding methods of the study (Lincoln & Guba, 1985). Peer debriefing focuses on having peer be participants to the researchers’ ideas and allowing those peers to offer insights and challenge the presented ideas (Spall, 1998). In addition to peers, having a senior colleagues and advisors can examine select samples allows for another time efficient manner to confirm that processes and themes are proceeding appropriately.

Finally, transferability relates to the feasibility of transferring the findings in the study to other samples or to the population based on the rich description of the participants in the original study. This is done by researchers mirroring the study with another subset population. The subset can be a similar demographic but in another institution or with different demographic to allow for contrast and comparison of the findings.

In Chapter 3, trustworthiness was established through application of a theoretical framework, peer debriefing, member checking, and data triangulation. The phenomenographic methodological approach allowed us to describe variations of the experiences of organic chemistry students as they approach studying in the course while searching for similarities and patterns in participants’ experiences. Interview data were examined for instances of how each participant utilized surface and deep approaches, and whether they tended to study individually or collaboratively. Instances were compiled and examined for emergent patterns and themes. Participants were classified based on how they described their overall approach to studying in the postsecondary organic chemistry course.
Assignment of individuals into their respective categories was based on codes that were adapted from operationalized work of Chin and Brown (2000) conceptualizing surface and deep approaches. In addition, collaborative and individual habits were operationalized from Tang’s (1993) collaborative learning. Discussions throughout data analysis between the researcher team members regarding how the coding scheme was applied to the data served as a foundation for trustworthiness (Lincoln & Guba, 1984). Additionally, trustworthiness of the conclusions was made through member-checking of themes from the interviews; in particular, students were asked to read and reflect on the themes and details from the first interview at the end of the second interview. Lastly, findings were triangulated through field notes by attending lecture periods for the course to understand methods employed by the course instructor, to identify strategies offered for how to best study, and to verify that the items asked in the interviews were not previously discussed but were similar in context to the material presented.

In Chapter 4, trustworthiness was established through peer debriefing and inter-rater reliability. For example, in weekly group meetings the relationship between role and codes were discussed with peer colleagues giving insights on the appropriateness and correctness of the relationship and challenging how the proposed progression related to the experience described by the peer leaders. In addition to peer colleagues, weekly discussions with the project’s principal investigator provided input and questions as to the rationales for coding decisions to ensure the analysis process was reasonable and trustworthy. To establish interrater reliability, twelve journal entries were randomly selected and reviewed by the project’s principal investigator. Sufficient agreement with the proposed themes was met for those entries after coding and discussion.

**Quantitative Methods**

Social scientists employ “quantitative methods to emphasize purposeful measurements and the statistical, mathematical, or numerical analysis of data collected through polls, questionnaires, and surveys, or by manipulating pre-existing statistical data using computational techniques” (p. 147,
Babbie, 2015). The emphasis of quantitative research is on the collection of numerical data relating to a certain phenomenon, with generalization of the phenomenon across groups of people (Babbie). Measurement is a component of quantitative methods and relates to how measurements are taken, analyzed, and validated (Hancock, Mueller, & Stapleton, 2010). Validity and reliability of measured constructs key to establishing trust in the research findings.

The data collected and analyzed in Chapter 5 is in the form of a survey instrument. From these data, factor analysis, both exploratory and confirmatory, were performed to determine construct validity. For exploratory factor analysis, adequacy of sample size, extraction of factors, retention of factors, rationale for lack of factor rotation, and interpretation are described. Next, for confirmatory factor analysis, estimation method, model fit, and reliability are described. Scale scoring is then described. Finally, an explanation is offered for how the data were analyzed using a Wilcoxon Signed-rank test to determine differences in the constructs before and after the peer leading experience.

Background on Survey Development

Survey development can be broken into three phases (Hinkin, 1998). The first phase is item identification and creation. This is primarily done through having a target latent variable that cannot be directly measured such as self-efficacy (Ghiselli, Campbell, & Zedeck, 1981). Once the items are created, the validity of their content is reviewed, usually by experienced researchers or practitioners. The scale itself is constructed in the second phase. This phase begins with scale construction which can include pre-testing the questions, administering the survey, reducing the number of items, and understanding how many factors the scale captures. In this phase the primarily construct validity is measured. Factor analysis is used to ascertain the redundancy and relationship of the items to the latent variable (Kim & Mueller, 1978). Exploratory factor analysis can be used to reduce the number of items. In the third phase (i.e., scale evaluation), number of dimensions are tested, and reliability and validity are assessed.
For the scales developed in Chapter 5, core ideas and items were used from a previously designed instrument, specifically the Teaching Assistant Professional Development (TAPD) survey (Wheeler, Maeng, Chiu, & Bell, 2017); TAPD originated from the College Teaching Self-Efficacy Scale (Navarro, 2005) and from the STEM Graduate Teaching Assistant-Teaching Self-Efficacy Scale (DeChenne, Enochs, & Needham, 2012). Changes to the TAPD were necessary to voice the items towards peer leaders and to remove items not related to peer leader expectations.

**Factor Analysis - General**

Factor analysis is a statistical method that models the covariance among a set of measured observed variables as a function of one or more latent constructs (Hancock, Mueller, & Stapleton, 2010). Factor analysis can be exploratory or confirmatory, either focusing on identifying a possible factor structure (EFA) or testing a proposed structure (CFA, Pett, Lackey, & Sullivan, 2003). The resulting structure of a factor analysis can be used to conceptualize the factor(s) as one or more latent constructs (Lawley & Maxwell, 1962). EFA explores those latent constructs and CFA provides confirming evidence for those latent constructs. Latent constructs are variables that cannot be directly measured and are estimated based other variables that can be measured (Child, 2006). Two constructs (i.e., self-efficacy and teaching beliefs) were studied in Chapter 5.

**Exploratory Factor Analysis**

Exploratory factor analysis (EFA) is used to establish construct validity (Pett, Lackey, & Sullivan, 2003). EFA is used when an a priori factor structure does not exist or when other tests of construct validity (i.e., confirmatory factor analysis, described in the next section) fail to validate a proposed structure (Pett, Lackey, & Sullivan, 2003). Results of an EFA provide a mathematical solution for how survey items are related to each other. These results can serve as a foundation for further confirmatory type analyses of factor structure with additional data. An EFA was necessary for the Chapter 5 scales, primarily because prior work done with similar items did not have a factor analysis (Wheeler, Maeng,
Chiu, & Bell, 2017). Various decisions are made when conducting exploratory factor analyses and interpreting those results:

**Adequacy of Sample Size.** Several guidelines exist for how large a sample must be in order to conduct an exploratory factor analysis. Factor analyses use Pearson product moment correlations (or other measures of association); therefore, the same assumptions that are relevant to association statistics are applicable to factor analysis (e.g., large sample sizes; Pett, Lackey, & Sullivan, 2003). The number of responses has been debated with ‘three to six times the number of survey items’ as a needed number of responses (e.g. Cattell, 1978); although, others have stated that a rule of thumb would be five respondents per item (Bryman & Cramer 1997). Ferguson and Cox (1993) suggest that an absolute minimum of 100 respondents is the number to be able to undertake factor analysis. Mundform, Shaw and Ke (2005) found that once a six to one item to factor ratio is met, the minimum sample size begins to stabilize regardless of the number of factors. The work completed in Chapter 5 exceeds all minimum thresholds with a total of 217 responses for 32 and 16 original items and at least six items per factor.

**Extraction of Factors.** The goal of factor analysis is to model the interrelationships among items. The primary focus being on the variance and covariance rather than the mean. Factor analysis assumes that variance can be partitioned into two types of variance, common and unique. Common variance is the amount of variance that is shared among a set of items. Thus, items that are highly correlated will also share a great deal of variance. Communality ($h^2$) is a definition of common variance that ranges between zero and one. Values closer to one suggest that the extracted factors will explain more of the variance of each individual item. Unique variance is the rest of the variance that’s not common. There are two types of unique variance: specific (that a particular item has a unique unexplained variance) and error (covering any random event that might have caused variance). To promote unique variance item reduction was performed on the self-efficacy scale based on Spearman correlations between scale items
to determine redundancy; values greater than 0.4 were examined with 15 items being removed due to correlating to a large number of other items.

Eigenvalues represent the total amount of variance that can be explained by any given principal component. Eigenvalues are also the sum of squared component loadings across all items for each component. This represents the amount of variance in each item that can be explained by the principal component. The teaching beliefs scale in Chapter 5 had five eigenvalues greater than one. These values allowed for a starting point from with to decide which factors to retain. Similarly the self-efficacy scale in Chapter 5 originally had four eigenvalues before reduction. Eigenvectors represent a weight for each eigenvalue. The eigenvector times the square root of the eigenvalue gives the component loadings. These loading can be interpreted as the correlation of each item with the principal component. The components can then be interpreted as the correlation of each item with the component. The square of each loading represents the proportion of variance explained by a particular component. If one keeps going adding the squared loadings cumulatively down the components, these values sum to one or 100%. This is also known as the communality, and in a Principal Component Analysis (PCA) the communality for each item is equal to the total variance.

Principal Component Analysis (PCA) is a commonly used method for data reduction by reducing a large number of variables into more manageable components (or factors). PCA assumes that there is no unique variance, therefore the total variance is equal to common variance. PCA is useful when parsimony is the goal, as it allows for the maximum amount of total variance with the smallest number of factors (Field, 2009). As previously mentioned our original scales in Chapter 5 had 32 and 16 items respectively and reduction in the number items was deemed appropriate after finding high values of correlation between several of the items.

Retention of Factors. Several criteria are used to determine the number of factors to retain in an exploratory factor analysis. While each item can be its own factor, such a solution raises concerns as
to the identity of the measured latent variables (Henson & Roberts, 2006), for a solution with each item as a factor would mean that there were problems with reliability. The goal of factor analysis is to explain the largest variance with the fewest number of factors to obtain parsimony; therefore, a single item factors are problematic as they would be difficult to replicate across different samples.

To determine the number of factors, criteria include parallel analysis, Kaiser’s criterion, and scree plots. Due to the categorical nature of the data analyzed in Chapter 5, parallel analysis could not be performed (Horn, 1965). Parallel analysis relies on a normality distribution that is difficult to identify when variation within data is lacking as is the case with dichotomous or ordered categorical data (Lubbe, 2019). Because of this, correlation coefficients and, as a consequence, factor analytic estimates (e.g., eigenvalues) may be biased leading to either an over or under estimation (Lubbe, 2019). Kaiser’s criterion states that factors are retained that have an eigenvalue greater than one (Diamantopoulos, Sarstedt, Fuchs, Wilczynski, & Kaiser, 2012; Lubbe, 2019); however, Kaiser’s criterion tends to create an over estimation of the number of factors (Lubbe, 2019). The eigenvalue represents the total amount of variance that can be explained by a given principal component (Myung, 2003). Starting from the first component, each subsequent component is obtained from partitioning out the previous component. Therefore the first component explains the most variance, and the last component explains the least.

A scree plot is a visual representation of the number of factors by eigenvalues (Cattell, 1966); the number of factors retained is determined at the “elbow” of the plot which corresponds to when the amount of each component’s eigenvalue approaches zero (Costello & Osborne, 2005). This represents the largest drop of when partitioning gives the biggest impact. For example, Figure 2.1 (from the study in Chapter 5) is a screen plot of the teaching beliefs subscale; based on the location of the “elbow”, two factors were retained.
Factor Rotation. When a factor structure has more than two latent constructs, there are an infinite number of alternative orientations of the factors in multidimensional space that can explain the data as accurately as the proposed structure (Fabrigar, Wegener, MacCallum, & Strahan, 1999). Determining which orientation is the best is done by the rule of “simple structure” or parsimony (Thurstone, 1947). Because of this, rotating each group of items toward multidimensional axes allows for a simpler interpretation of the factor structure (Osborne, 2015). Two commonly used rotation methods are orthogonal and oblique. Orthogonal has the factors uncorrelated to each other and oblique has the factors correlated (Browne, 2001). When multiple factors are appropriate, items should fall into a simple structure wherein items only load onto one factor; cross-loading items should be examined for appropriate inclusion. The relationship of each variable to the underlying factor is expressed by factor loading. Factor loadings can be interpreted like standardized regression coefficients, meaning the closer to a value of 1.0 the stronger the association. Factor loadings of a variable measures the amount to which the variable is related with a given factor.
When optimizing the teaching belief scale in Chapter 5, the two factors observed were assumed to correlate with each other. However, upon inspection of the two-factor structure, one factor was a collection of five items that would be considered non-supportive of social constructivism. When those items were reversed coded, the same EFA structure remained; therefore, the items were removed. The remaining eight items load onto one factor.

**Interpretation.** Factors need to be examined to ensure theoretical meaning. For example, in Chapter 5, an item was removed because it did not sufficiently load (< 0.300) on the factor; and, upon reexamining the item, it was determined that the item did not have a theoretical reason for being on the proposed scale. A factor is generally considered to need to have a minimum of three items loading on a factor (Marsh, Hau, Balla, & Grayson, 1998). All loadings above the 0.30 threshold needed to be considered valid (Costello & Osborne, 2005), this does not mean that items lower than the threshold need to be excluded. In Chapter 5, two items that did not significantly load (<0.300); given the theoretical appropriateness of these items, the items were retained in the scale. Bandalos and Finney (2019) suggested retaining any questionable variable until further research can be done to verify if the transgressing variable repeats upon replication of the study.

**Confirmatory Factor Analysis**

Confirmatory factor analysis (CFA) is used when a hypothetical or empirically supported structure exists for an instrument. CFA, like EFA, provides evidence for construct validity (Pett, Lackey, & Sullivan, 2003). In the work described in Chapter 5, EFA solutions were confirmed using CFA.

Data used in the CFA cannot be the same data used to perform the EFA; this is done to minimize Type II error, an error that occurs when one accepts a null hypothesis that is actually false. A CFA is used to test the hypothesis of the factor structure; if the same data were used in a CFA, the hypothetical, proposed structure will be correct by definition (Fokkema & Greiff, 2017).
**Estimation Method.** A common algorithm used for CFA is maximum likelihood (ML; Sweet & Grace-Martin, 1999). ML has the assumption that the data are continuous. Data collected for the study in Chapter 5 are ordinal, and thus ML is not appropriate; therefore, weighted least squares mean and variance adjusted (WLSMV) is more appropriate for my ordinal data. Brown (2006) states that, “the WLSMV estimator is a robust estimator which [sic] does not assume normally distributed variables and provides the best option for modelling categorical or ordered data” (pg. 153).

**Model Fit.** CFA is a technique used to test a specific hypothesis about the structure of given data; therefore, fit statistics are used to determine how aligned the data are with the proposed factor structure. There are multiple fit indices used to evaluate CFA models (e.g. root mean square error of approximation, comparative fit index). These indices are often used in applied research to reject or accept a proposed model (e.g., Hu & Bentler, 1999); however, the cutoff values for fit indices are guidelines collectively used to make an argument for construct validity. Marsh, Hau, and Wen (2004) warn against using the cutoff values when making an absolute validity determination.

In Chapter 5, a parsimony-adjusted index to measure fit, i.e. root mean square error of approximation (RMSEA), was used to decide about model fit. RMSEA measures the discrepancy between the observed and implied covariance-variance matrices (Curran, Bollen, Chen, Paxton, & Kirby, 2003). A penalty is incorporated into this index for model complexity due the nature of fit increasing with model complexity (Curran, Bollen, Chen, Paxton, & Kirby, 2003). RMSEA measures how far a hypothesized model is from the ideal model; therefore, a lower RMSEA value is ideal. Recommended cutoffs are <0.05 for good fit and <0.08 for acceptable fit (Hu & Bentler, 1999).

The other index used in the Chapter 5 study is an incremental fit index: the comparative fit index (CFI). CFI compares the fit of the model to a null or baseline model (Hu & Bentler, 1999). Acceptable cutoffs are generally above 0.90 (Browne & Cudeck, 1993). Other cutoff values have been suggested by Hu and Bentler for studies that evaluate continuous data; however, Xia & Yang (2019) found that these
cut off values are inconsistent for ordinal data. Therefore, like with RMSEA, CFI values are interpreted using cutoff values as guidelines.

**Reliability.** Reliability statistics are used to show that the scales are producing consistent data (Cortina, 1993; Murphy & Davidshofer, 2005). Internal consistency is one measure of internal structure. In Chapter 5 it was measured using McDonald’s omega values. McDonald’s omega is a better alternative to Cronbach’s alpha in that the items do not have to be tau-equivalent (Deng & Chan, 2017). The tau-equivalent measurement model necessitates that the path coefficients from the latent factor to the measured items are constrained equally. In addition, two assumptions that alpha has that omega does not is that the average loading to be above 0.7 and that every difference between each factor loadings when compared to the average loading 0.2 or less. The factor solution reported in Chapter 5 violates the assumptions of alpha; therefore, omega was used for reliability. An omega coefficient greater than 0.60 indicates acceptable consistency (Cortina, 1993). Omega coefficient scores range from 0 to 1 with higher scores indicating that the measurement is precise, reproducible, and consistent.

**Scale Scoring**

A scaled score is a conversion of a respondent’s raw score on a scale to a common measure that allows for a numerical comparison between participants. Classical test theory (CCT) argues that observed scores of respondents to scales is based on assumptions made about how individuals responded to the scale, test, or measure (Furr, 2011). A basic assumption of CTT is that observed scores are determined by the summation of true score and measurement error (Furr, 2011). A second assumption is that this error is random (Furr, 2011). By averaging or aggregating the scores of a scale, a researcher can more accurately account for these measurement errors, thus adding internal reliability to the data collected. Rocabado, Komperda, Lewis, and Barbera (2020) recommended using weighted values for scale scores because the process determines in advance the relative importance of each data point. In contrast, by calculating a simple average or mean, all numbers are assigned equal weight.
While weighted scores are valid, this was not pertinent because of the desire to have the scales be readily accessible by peer leader trainers, and thus potentially non-statistics trained faculty. Advance methods give more reliability to the results if done correctly; however, if determined incorrectly, results could be misinterpreted. In Chapter 5, average scores were used, which account for some measurement error while still maintaining user-friendliness to the intended audience. Higher scores are interpreted to mean higher perceived constructivist teaching beliefs, and higher teaching self-efficacy.

**Wilcoxon-Signed Rank Test**

The Wilcoxon signed-rank test is a non-parametric test used when ascertaining if two dependent samples from the same population have similar distributions (Wilcoxon, 1992). The Wilcoxon signed-rank test compares a sample median against a hypothetical median. Finding the differences between first and second observations is followed by ranking the absolute values of differences from first to last. Calculation of the sum of the ranks of the negative and positive differences is then made. If the number of pairs $n(n+1)/2$ is greater than 20, one can use a normal approximation.

In Chapter 5, significant differences were observed between the pre/post survey results for peer leaders in both the teaching beliefs and self-efficacy scales. These differences had small to medium effect sizes: $r = z / (n_{\text{pre}} + n_{\text{post}})^{-1}$ (Cohen, 1988; Pallant, 2007).

**References**


Clark, A., Pratt, J., Cruz, D., & Raker, J. R. (in preparation) “My normal study habits failed me.” A phenomenographic study of student approaches to studying organic chemistry.


Chapter 3

“My normal study habits failed me.” A phenomenographic study of student approaches to studying organic chemistry

Note to reader

This chapter is in preparation to be submitted for peer review.

Clark, A., Pratt, J. M., Cruz, D., & Raker, J. (in preparation) “My normal study habits failed me.” A phenomenographic study of student approaches to studying organic chemistry.

The 1st and 2nd interview protocols are provided in Appendix A.

This work was published with co-authors. Daniel Cruz-Ramírez de Arellano is an instructor of organic chemistry at the University of South Florida and provided feedback about the manuscript and allowed students to be interviewed from his classes. Justin M. Pratt was a postdoctoral researcher in the Raker Research Group, now a faculty member at Maine Maritime Academy, and provide expertise with trustworthiness and analysis. Dr. Jeffrey R. Raker is the principal investigator for this project.

Abstract

Socially constructed, deep approaches to learning are foundational to well-developed understandings of organic chemistry, in particular understanding of what is happening in a reaction mechanism and why reactions occur. Research and anecdotal accounts suggest that students typically do not approach organic chemistry courses in a way that is productive for learning. More surface-level and memorization-based approaches are used by students in isolation and can lead to underdeveloped understandings of course content. We explored the study strategies of sixteen postsecondary students through in-depth interviews conducted at two time points across the first semester of a yearlong course in organic
chemistry. Through a multi-framework, holistic analyses of these data, findings suggest a potential interplay between surface/deep learning and individual/collaborative study approaches. Our data suggest that instructors have an opportunity and responsibility to model more social constructivist and deeper learning strategies to promote student learning and performance in organic chemistry.

Introduction

Organic chemistry has a reputation of being a “weed out” course. Weston, Seymour, Koch, and Drake (2019) defined “weed out” as a course as greater than 20% drop-fail-withdraw-incomplete rate, lower level, and required for a STEM degree. Organic chemistry unique in being a second-year course, whereas most gateway courses are first-year courses (e.g., general chemistry, calculus). Estimates suggest that up to 50% of students switch out of STEM because of gateway chemistry courses (Weston, Seymour, Koch, & Drake, 2019). A focus on success through performance on exams in organic chemistry is even more meaningful considering the added barrier this course presents to aspiring scientists, engineers, and medical professionals.

Success of students in organic chemistry courses is dependent, in part, on approaches to learning the course material. Grove and Bretz (2012) found that commitments to learning influenced how students approached studying; Anderson and Bodner (2008) found that students who approached learning organic chemistry by memorizing disproportionately struggled in the course. Research also shows that metrics used to predict general chemistry performance (e.g., SAT-Math) do not predict organic chemistry performance (Spencer, 1996; Pursell, 2007). Understanding how and why students struggle has been the goal of multiple studies in organic chemistry courses (e.g., Cooper & Stowe, 2018; Anderson & Bodner, 2008; Grove & Bretz, 2010). Additionally, organic chemistry education studies have focused on difficulties learning particular concepts and skills (e.g., Galloway, Leung, & Flynn, 2018; McClary, & Talanquer, 2011), revising the organic chemistry curriculum and the broader chemistry curriculum (e.g., Flynn, & Ogilvie, 2015; Cooper, Stowe, Crandell, & Klymkowsky, 2019), and developing
impactful learning experiences for targeted concepts (e.g., Dood, Fields, Cruz-Ramírez de Arellano, & Raker, 2019; Grove, Cooper, & Rush, 2012). Missing from the literature is an understanding of how students construct their knowledge and skills outside the classroom (e.g., through group study sessions). The work reported herein focuses on the learning approaches students use when studying organic chemistry.

The authors were motivated by how the average performance of students on midterm exams in our first-semester organic chemistry course drops by more than 20 percent during the second half of the term. At research setting, all students are involved with collaborative learning in general chemistry courses; we were interested in whether collaboratively learning spontaneously occurs in organic chemistry courses. This led us to use the surface and deep learning framework of Marton and Saljo (1976) and by Tang’s (1993) interpretation of individual and collaborative approaches to studying to explore learning in organic chemistry. Marton and Saljo’s (1976) framework delineates that surface learners rely on memorization while deep learners use metacognitive strategies when learning course material; Flavell (1976) defined metacognition as “knowledge concerning one’s own cognitive processes and products, or anything related to them” (pg. 232). Rickey and Stacy (2000) added that the importance of teaching metacognition is an indispensable aspect of chemists’ thinking and students’ learning about chemistry; however, due to lack of awareness or the mistaken belief that it is not a science teacher’s responsibility to increase metacognitive ability within students, in a recent review on metacognition in chemistry education has shown little research has been done on this in organic chemistry (Lavi, Shwartz, & Dori, 2019). Tang’s (1993) individual and collaborative approaches to studying describe how students approach studying tasks in relation to their interaction with others. While collaborative and deep learning approaches are beneficial in every course, success using individual and surface approaches can negatively impact student motivation to adopt more beneficial study approaches when their original strategies fail them.
Approaches to Learning

The role study approaches have on learning has been studied in multiple contexts: broadly in STEM (Chin & Brown 2000; Marton & Saljo 1976, 1984) and in targeted disciplines including biology (Rybczynski & Schussler, 2011; Tomanek & Montplaisir, 2004) and general chemistry (Ye, Oueini, Dickerson, & Lewis, 2015; Bunce et al 2017; Sinapuelas & Stacy 2015). A meta-analysis showed that, among noncognitive predictors, study habits have a strong correlation with performance (Credé & Kuncel, 2008). We concur with Graulich (2015) that similar studies in organic chemistry courses are necessary but lacking. The distinctiveness of the course, and our interest, originates from high attrition rates (>40%) and the importance for entrance to post-graduate programs (e.g., medical school). Thus, the impact of “having to pass organic chemistry to reach ‘X’ career goal” likely plays a role in study approaches employed and the relationship of those approaches to performance (Lovecchio & Dundes, 2002). We, therefore, conjecture that approaches to learning differ for students taking organic chemistry compared to other courses.

Measuring study approaches outside classroom contexts is difficult due to the complexity of making such observations (c.f., Christian & Talanquer, 2012), the necessity for experience sampling methods (c.f., Ye, Oueini, Dickerson, & Lewis, 2015), and reliance on self-report data. We, accordingly, found few such investigations in the literature; however, such understanding has the potential to inform why students who are predicted to perform well in their organic chemistry course, based on prior success, fail to do so. Particularly, we are interested in the degree of beneficial study approaches used by students given the “make or break” character of organic chemistry.

Surface and Deep Approaches

Marton and Saljo (1976) offered a model that delineates surface and deep approaches to learning rooted in metacognition. Learners using surface approaches tend to give shallow descriptions when asked to explain their answer to an assessment item. Students with a surface approach tend to
memorize facts that manifest as perceived understanding but lack foundational context; the surface approach can inhibit a student’s ability to connect concepts and skills, and long-term retention. Deep approaches to learning, conversely, focus on a learner engaging in meaningful construction of concepts, including ‘testing’ how those ideas relate to prior knowledge. Deep learners tend to be aware of their learning. The model presented by Marton and Saljo (1976) is presented as a continuum with learners have a preference toward more surface or deep approaches depending on the context. A key component of Marton’s clarifying work on surface and deep approaches is based on the notion of describing the different “attitudes” shown by students who adopted deep-level or surface-level processing when reading a text.

The work of Marton and Saljo (1976) has been extended by Biggs (1991) and Entwistle (1997). Biggs and Entwistle elaborated on individual traits (e.g., motivation and attitudes) and a learner’s ability to explain why surface or deep learning approaches are used; this is in contrast the context-specific rationale for preferred study approaches asserted by Marton and Saljo. While the Biggs model focuses on the instructor, it suppresses the role other factors play on learning such as content and the roles others play in knowledge construction. The latter, we argue, is an important component of organic chemistry courses. Entwistle’s focuses more on students having a disposition for either surface or deep approaches; this consideration, though, minimizes the importance of the broader learning context. The model presented by Marton and Saljo best aligns with prior research in chemistry education and motivation to conduct our study.

A critique of the work of Marton and Saljo (1976) is its lack of definitions for surface and deep approaches (c.f., Webb, 1997a, 1997b; Howie & Bagnall, 2013). In the spirit of the model presented by Marton and Saljo, Chin and Brown (2000) operationalized surface and deep approaches through five characterizations: generative thinking, nature of explanations, asking questions, metacognitive activity, and approach to tasks. Generative thinking focuses on whether explanations are lacking details (i.e.,
surface) or are elaborate and rich (i.e., deep). The nature of explanations focuses on how individuals explain the unobservable: explanations without a why component (i.e., surface) or explanations containing analogies and hypothetical examples of what is happening (i.e., deep). Asking questions of the material is a contrast between closed questions that can be answered with simple facts (i.e., surface) and open-ended questions that require explanation (i.e., deep). Metacognitive activity is absent in surface approaches, with reflective thinking associated with deep approaches. When considering the asking questions and metacognitive activity categories, students utilizing surface approaches tend to have limited insight into their learning and are unable to answer questions that require more than a restated fact to answer. Finally, the approach to tasks category considers how learners respond to adversity and difficulty: students utilizing a surface approach might easily give up, while students utilizing a deep approach tend to persist.

Elements of surface and deep approaches to learning appear in organic chemistry education research; however, full conceptualizations have not. For example, Anderson and Bodner (2008) used Skemp’s (1979) Theory of Intelligent Learning when characterizing why “good” students struggle with learning the “why” of organic chemistry; they noted that relationship learning (similar to deep) led to greater learning than instrumental learning (similar to surface). Additionally, Grove and Bretz (2012) used Novak’s (2002) Theory of Meaningful Learning, noting that students approached the course from a rote memorization (i.e., surface) or from a meaningful learning approach (arguably deep). These investigations in the context of organic chemistry, though, lack a focus on metacognition and collaborative study activities.

**Individual and Collaborative Approaches**

Social constructivism (Piaget & Elkind, 1968; Vygotsky, 1978) provides a second lens for considering approaches to learning; while the model presented by Marton and Saljo (1976) is more learner-centric, social constructivism is multi-learner-centric. Vygotsky argued that learning occurs in the
collective minds of learners; knowledge is gained by the exchange of ideas between others. While Vygotsky was not a social constructivist in the strictest sense, his ideas on social learning are consider a foundation to the ideology of collaborative work (e.g., Windschitl, 2002; Bodner, 1986; Cooper & Stowe, 2018; Tien, Roth, & Kampmeier 2002). Bargh and Schul (1980) argued that both teacher and learner benefit from elaborated help. Teachers mentally clarify and reorganize material in order to make it understandable to others; this process helps the learner develop new perspectives and fill in gaps in their understanding. As such, knowledge gained through collaborative studying approaches has the potential to lead to more deep or meaningful learning in comparison to more individual (or isolated) studying approaches.

Tang’s (1993) study of physiotherapy students revealed that students who worked collaboratively on an assignment utilized higher-level cognitive strategies than students who worked individually. Collaborative groups were spontaneously formed, student-centered, and students had positive perceptions of the experience. However, Tang (1993) concluded that because groups self-formed without guidance, some students may not fully understand the importance of their collaborative effort. In our study, groups formed and reported by participants were spontaneously formed groups; thus, Tang’s perspective fits well with our study.

When students spontaneously form groups, it may be unclear as to how students should engage with each other in order to promote deep, meaningful learning. While observing organic chemistry students in self-formed study groups, Christian and Talanquer (2012) found that students focused on instructor-suggested problems. Students less frequently created their own problems or questions. Most students were genuinely interested in learning the chemistry concepts; however, students lacked demonstration of important cognitive and metacognitive tools to think about the content more productively. Without an understanding of how to approach learning collaboratively, most students took passive roles in their study groups (i.e., listening to explanations rather than generating
explanations). These behaviors are similar to those reported in biology course contexts (Tomanek & Montplaisir, 2004; Rybczynski & Schussler, 2011).

**Figure 3.1**
*Overlap of Surface-Deep Approaches to learning and Individual-Collaborative Approaches to Studying.*

**Summary of Learning Approaches**

The model presented by Marton and Saljo (1976) of surface and deep approaches coupled with Tang’s (1993) individual and collaborative approaches provides a nuanced lens from which to consider learning in organic chemistry courses (see Figure 3.1). Collectively, these frameworks suggest that a deep, collaborative approach to studying will lead to more meaningful learning. Students who approach the course from a surface, individual approach can be characterized as preferring to study alone, resisting help from peers and knowledgeable others possibly out of fear, prone to giving up easily when presented with difficult material, engaging in little metacognition, and providing limited explanations for “why” when probed on assessments and authentic tasks. Students who approach the course from a surface, collaborative approach can be described as preferring to study in groups, “receiving” knowledge from others, prone to giving up, exhibiting little metacognition, and offering limited explanations.

Students who approach the course from a deep, individual approach prefer to study alone, are willing to
“teach” others, persistent when faced with learning difficult material, engage in metacognition, and articulate detailed explanations. Finally, students who approach the course from a deep, collaborative approach engage in group studying, prefer sharing and receiving help, engage in metacognitive activities, and articulate detailed explanations. Based on these theoretical foundations, we assert that the deep, collaborative approach is most beneficial to learning in organic chemistry courses.

**Research Purpose**
Our purpose is to understand student approaches to studying and how those approaches lead to meaningful learning in an organic chemistry course. Our assertion is that deep and collaborative approaches lead to achievement measured by exam performance. This assertion situates our work such that an over reliance on memorization and lack of metacognitive awareness could lead to less meaningful learning. Our work is guided by the question: What study approaches are students using in an organic chemistry course?

**Methodology**
Two semi-structured interviews were conducted; one towards the beginning of an organic chemistry course and one near the end. Interviews probed the approaches to learning used in the course, including how those approaches may have changed between the two interviews. Data were analyzed using a phenomenographic methodology coupled with theory-situated coding (Marton, 1981). Phenomenography is a research tradition aimed to answer questions about thinking and learning in education and to create descriptive categories of various phenomena (i.e., categories of participants’ approaches to studying organic chemistry). Theory-situated coding provided a means to organize study approaches using the two theoretical foundations of this study (i.e., Marton & Saljo, 1976; Tang, 1993).

**Instructional Context**
Participants were recruited from the first semester of a yearlong postsecondary organic chemistry course at a research-intensive university in the Southeast United States. Participants had previously completed a yearlong general chemistry course sequence earning a “C” grade or higher.
Sections of organic chemistry enroll between 180 and 240 students; the institution offers multiple sections of the course each term. While student participants were from multiple course sections, all participants were recruited from sections taught by the same professor.

Each section of the course met for two 75-minute class periods each week, complemented by a weekly 50-minute recitation lead by a teaching assistant. The 12th edition of Solomons, Fryhle, and Snyder’s (2016) Organic Chemistry textbook was used. Wiley Plus was a required online homework system. Course topics included organic nomenclature, physical and chemical properties of organic compounds, and mechanisms of alkane, alkene, alkyne, alkyl halide, and alcohol reactions. Students took four in-term, open-ended exams and one multiple-choice final exam; students were able to “drop” their lowest in-term exam grade. Final course grades included the three highest in-term exam scores (50%), final exam score (25%), as well as online homework and participation in weekly discussion sections and lecture (25%). Students were provided with guidance during each lecture period on how to prepare for exams.

Participants

Sixteen students were recruited via email. Participants were taking the course for the first time and had completed the second semester of their general chemistry course sequence in a course that used a flipped Peer-Led-Team-Learning (PLTL) approach (i.e., half of the lecture periods had peer leaders helping students complete a worksheet of open-ended problems). Data were collected until saturation was reached. Corbin and Strauss (2008) argued that saturation is more than finding ‘no new codes’ as new data are analyzed but encompasses fully developed categories including variations and connections; a softer version of saturation is to examine how prevalent the codes are across data from a predetermined sample size. Participants varied by sex, race/ethnicity, and major, and their demographics are reflective of the population of students in the course in the research context. Participants included five males and eleven females; nine Caucasians, two Asians, one Black, one
international, one unspecified, and two Hispanics (note: that Hispanic is considered a race/ethnicity at the research setting). Majors included seven biomedical science students, three integrated animal biology students, two cell and molecular biology students, two health science students, and one environmental science and policy student.

**Data collection**

Two semi-structured interviews were conducted; one after the first exam and the second before the final exam of the semester. Participants received a $15 gift certificate to the university bookstore for completing each interview ($30 total). The study was approved by the Institutional Review Board at the research setting. Interviews were conducted and transcribed verbatim by the first author. All identifying information was removed from transcripts, and participants were assigned a pseudonym. Two interviews were used because of the exploratory nature of our study and to identify changes with approaches to learning that would occur once the participants took additional course examinations.

The first interview (see Appendix A) was designed to elicit approaches to studying that participants used for other non-chemistry courses, what experiences shaped their general chemistry experiences, how they approached organic chemistry before and after receiving their first exam score, and how they approached solving two acid-base examination-style, constructed-response items similar to previous work on acid-base reactions (c.f., Cooper, Kouyoumdjian, & Underwood, 2016) using a think-aloud protocol (Ericsson, & Simon, 1993). Lewis acid-base theory is a foundational component for understanding organic chemistry reaction mechanisms; previous research has shown that students who demonstrate an understanding of the Lewis acid-base model have higher performance in organic chemistry (Dood, Fields, & Raker, 2018; Cooper, Kouyoumdjian, & Underwood, 2016). The acid-base items used were similar to examples covered in lecture and on course examinations.

The second interview (see Appendix A) covered similar topics, including approaches to studying in the course, how the participants approached two constructed-response items similar in format to
exam questions, and member checking of themes from the first interview. The two exam items involved predicting the product(s) of reactions and using arrows to show electron flow for the reactions; substitution and elimination reactions were chosen, as these reactions represent the fundamental mechanisms used throughout the course. As with the Lewis acid-base prompts, research has shown that students who are able to explain what is happening in these reactions and why the reaction occurs have a deeper and more meaningful understanding of organic chemistry (Cooper, Kouyoumdjian, & Underwood, 2016).

**Data Analysis and Trustworthiness**

Our analysis was framed by the model of surface and deep approaches by Marton and Saljo (1976) as operationalized through Chin and Brown’s (2000) five category lens, and Tang’s (1993) operationalization of individual and collaborative approaches. In addition, we used a phenomenographic framework (Marton, 1981; 1986) in data analysis. The phenomenographic approach allowed us to describe variations of the experiences of organic chemistry students as they approach studying in the course while searching for similarities and patterns in participants’ experiences. Interview data were examined by the first author for instances of how each participant utilized surface and deep approaches, and whether they tended to study individually or collaboratively. Instances were compiled and examined for emergent patterns and themes. Participants were classified based on how they described their overall approach to studying in the postsecondary organic chemistry course. Chin and Brown’s (2000) five categories for differentiating between surface and deep approaches (see Table 3.1) was used as our coding scheme. Additionally, social constructivism coupled with Tang’s (1993) conceptualization of collaborative learning (see Table 3.1) was used as our other coding scheme. Discussions throughout data analysis between the first author and corresponding author regarding how the coding scheme was applied to the data served as a foundation for trustworthiness (Lincoln & Guba, 1984). Disagreements on individual categorizations centered on whether individuals were more surface or deep. Fourteen
participants had similar categorizations based on both interviews. Discrepancies were mainly between their first interview and their second interview. Due to the second interview looking at a more complete version of their approaches to learning it was given the greater weight for assignment, however it should be noted that surface and deep are not meant to be permanent assignment of a student’s ability and therefore adjustments are expected. For two participants, (Casper and Sylvain) debate was given about whether they were more surface or deep; both tended to exhibit more surface codes in the second interview and were assigned as such. Second, peer debriefing through presentations to chemical education researchers (group meetings, workshops, and conferences) further established the trustworthiness of our code applications and interpretations.

**Table 3.1**  
*Coding Scheme*

<table>
<thead>
<tr>
<th>Code</th>
<th>Surface</th>
<th>Example</th>
<th>Deep</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generative Thinking</td>
<td>short, lacking details, evasive response, “I don’t know”</td>
<td>“I don't know exactly; I just know that it gets protonated”</td>
<td>elaborate, rich details</td>
<td>“Cl minus is a halogen with a negative charge, and this is very hindered. So I feel like [water] would leave first 'cause [Cl-] is not gonna want to attack [tertiary carbon]”</td>
</tr>
<tr>
<td>Nature of Explanations</td>
<td>black box, magic structural, visible</td>
<td>“Well what I was looking at was, I know that O and Cl are very electronegative, so I just swapped them.”</td>
<td>analogies, hypothetical examples, implicit theoretical entities</td>
<td>“you're gonna form a carbocation as your intermediate and then you've got a Cl minus with a lone pair. And that's attracted to the positive.”</td>
</tr>
<tr>
<td>Asking Questions</td>
<td>closed, answer with a fact, avoid lacking</td>
<td>“I also hate going to ask questions 'cause I feel like it makes me look more stupid than I really am”</td>
<td>wonderment, theorize</td>
<td>“electron transfer is like, that happens in every reaction then what isn't an acid base?”</td>
</tr>
<tr>
<td>Meta-cognitive</td>
<td></td>
<td>“It was not working with me; it just was not sticking for the life of me. I couldn’t tell you why.”</td>
<td>reflective thinking</td>
<td>“to talk through ideas; if I don't do the same thing with science, I don't do well.”</td>
</tr>
</tbody>
</table>
Table 3.1 (continued)

<table>
<thead>
<tr>
<th>Approach to Tasks</th>
<th>give up on failure</th>
<th>persistent</th>
<th>“you're having problems just don't try to keep working on it, put it aside, do something else, come back to it, it'll probably make more sense after you spent a little time disengaging”</th>
</tr>
</thead>
<tbody>
<tr>
<td>use ideas of others, not original</td>
<td>“it just was like drilled into our head that water is a better leaving group than pure acid or pure base. I don't really know, it's a better nucleophile, I guess.”</td>
<td>generate own ideas</td>
<td>“so I looked for common themes..., oh that's literally the same concept I learned”</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Individual</th>
<th>Example</th>
<th>Collaborative</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study Preference</td>
<td>alone</td>
<td>“I studied best by myself.”</td>
<td>group</td>
<td>“We’ll decide on what to do and we’ll all do it together.”</td>
</tr>
<tr>
<td>Help Seeking</td>
<td>avoid</td>
<td>“then if there's something I don't get instead of getting help from someone else, I try to figure it out on my own”</td>
<td>sought after</td>
<td>“cause I've asked a few questions, and I generally felt like an idiot the whole time so that's cool. But I rather just do it in [the library] 'cause at that point, we all feel like idiots so it's fine.”</td>
</tr>
</tbody>
</table>

Additionally, we further supported the trustworthiness of our conclusions through member-checking themes from the first interview; students were asked to read and reflect on the themes and details from the first interview at the end of the 2nd interview to avoid bias. Data were triangulated by comparing self-reported approaches to studying, examination scores, and responses to the cognitive tasks during both interviews. Furthermore, the first author attended lecture periods for the course to understand methods employed by the course instructor, to identify strategies the instructor offered for how to best study, and to verify that the items asked in the interviews were not previously discussed but were similar in context to the material presented. These observations and field notes triangulate and complement the interview data.
Results

Results are presented by framework followed by a summary of performance in the course. These results provide a foundation for our claim that students need better guidance on how to integrate deep, collaborative studying in their study of organic chemistry. We first present evidence of surface and deep approaches, followed by individual and collaborative approaches. These approaches are based on continuums; as such, we aligned participants into the approach most exemplified by their self-reported behaviors and explanations to the think-aloud problems. Table 3.2 provides a summary of these categorizations and course performance for the sixteen participants; discussion of categorizations (e.g., deep-collaborative), interpretation of general chemistry and examinations scores, are further elaborated in subsequent Results subsections.

Table 3.2
Participants - Approaches Category, General Chemistry (GC) Letter Grades, and Midterm Exam Scores

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Approaches Category</th>
<th>GC1</th>
<th>GC2</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
<th>Test 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bernadetta</td>
<td>surface-individual</td>
<td>A</td>
<td>A</td>
<td>85</td>
<td>86</td>
<td>67</td>
<td>62</td>
</tr>
<tr>
<td>Casper</td>
<td>surface-individual</td>
<td>A</td>
<td>B</td>
<td>94</td>
<td>89</td>
<td>67</td>
<td>57</td>
</tr>
<tr>
<td>Dorothea</td>
<td>surface-individual</td>
<td>N/A</td>
<td>B-</td>
<td>37</td>
<td>17</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Leonie</td>
<td>surface-individual</td>
<td>AP</td>
<td>A</td>
<td>50</td>
<td>0</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Marianne</td>
<td>surface-individual</td>
<td>A</td>
<td>B+</td>
<td>79</td>
<td>75</td>
<td>29.5</td>
<td>62</td>
</tr>
<tr>
<td>Annette</td>
<td>deep-individual</td>
<td>A</td>
<td>A</td>
<td>95</td>
<td>84</td>
<td>90</td>
<td>89.5</td>
</tr>
<tr>
<td>Dimitri</td>
<td>deep-individual</td>
<td>A</td>
<td>A</td>
<td>97</td>
<td>96</td>
<td>94</td>
<td>99</td>
</tr>
<tr>
<td>Edelgard</td>
<td>deep-individual</td>
<td>A</td>
<td>A</td>
<td>83</td>
<td>91</td>
<td>71</td>
<td>75.5</td>
</tr>
<tr>
<td>Lysithea</td>
<td>deep-individual</td>
<td>AP</td>
<td>A</td>
<td>89</td>
<td>85.5</td>
<td>83</td>
<td>95.5</td>
</tr>
<tr>
<td>Petra</td>
<td>deep-individual</td>
<td>A</td>
<td>A</td>
<td>75</td>
<td>93</td>
<td>86</td>
<td>82.5</td>
</tr>
<tr>
<td>Hilda</td>
<td>surface-collaborative</td>
<td>C+</td>
<td>C-</td>
<td>78</td>
<td>57</td>
<td>47</td>
<td>54</td>
</tr>
<tr>
<td>Ingrid</td>
<td>surface-collaborative</td>
<td>A-</td>
<td>C+</td>
<td>67</td>
<td>46.5</td>
<td>51.5</td>
<td>39</td>
</tr>
<tr>
<td>Mercedes</td>
<td>surface-collaborative</td>
<td>C</td>
<td>C</td>
<td>70</td>
<td>69</td>
<td>38</td>
<td>50</td>
</tr>
<tr>
<td>Sylvain</td>
<td>surface-collaborative</td>
<td>A-</td>
<td>A-</td>
<td>86.5</td>
<td>80</td>
<td>70</td>
<td>65.5</td>
</tr>
<tr>
<td>Ashe</td>
<td>deep-collaborative</td>
<td>A</td>
<td>A</td>
<td>73</td>
<td>87</td>
<td>74.5</td>
<td>77</td>
</tr>
<tr>
<td>Claude</td>
<td>deep-collaborative</td>
<td>B</td>
<td>A</td>
<td>88.5</td>
<td>90</td>
<td>83</td>
<td>91.5</td>
</tr>
</tbody>
</table>

Note. “GC1” means the first semester of general chemistry. “GC2” means the second semester of general chemistry. “AP” means credit for the course was earned via Advanced Placement Credit. “N/A” means not available. Hilda repeated “GC2” because her original grade would not meet the prerequisite for organic chemistry.
Surface Learning

Students approach their learning in postsecondary courses through a lens of ‘what works for them,’ constructed through prior schooling experiences (Wingate, 2007; Bunce et al., 2017). Surface approaches include ‘cramming’ for an exam and memorizing answer patterns rather than learning how to generate correct explanations and solutions; students adapt their study approaches to be more successful (i.e., highest grade) on course assessments. Participant Mercedes stated that, for her, the fact that organic chemistry uses free-response tests instead of multiple-choice, created difficulty:

The test format really, I feel like I just feel like if it was multiple choice, I’d get it. I feel like I would definitely get the higher grade that I wanted for all of them if they were multiple choice, … It was just the time it took to memorize everything, and knowing how to apply them really, well, was really difficult for me. (2nd interview)

Surface approaches also have an avoidance component, wherein learners result to ‘gaming’ their learning rather than confronting difficult material; for example, Bernadetta described this tactic:

When there's something I'm studying and there's a difficult concept, rather than me trying to figure out why don't I understand this, I just think, I hope that's not on the exam, I don't wanna study that. And then it pops up and that's where my points are lost. (1st interview)

Students employ such approaches because they are ‘workable.’ Annette exemplified this when describing a non-chemistry course: “Our [non-chemistry] professor gave us a review packet, so I just did that twice over and then reviewed all the conceptual stuff on the day of the exam and I got a really good grade on it. So, it works” (2nd interview). In the organic chemistry course, a summary packet was prepared by the instructor for examinations three and four. The instructor used class time to explain the summary packet and how they envisioned students utilizing the summary packet as a study tool. Of our
participants, fifteen reported using surface-like approaches in their non-organic chemistry courses; nine participants (Bernadetta, Casper, Dorothea, Hilda, Ingrid, Leonie, Marianne, Mercedes, Sylvain) reported mainly surface-like approaches in their organic chemistry course.

Evidence of surface approaches were corroborated when responding to the think-aloud assessment items. Participants using surface approaches were unable to provide meaningful explanations for how they generated answers and were unable to respond to “why” questions as to choices made when constructing their answers. When Ingrid was asked by the interviewer “What makes water a good leaving group?”, something they just claimed, she responded, “I don't know, I just, it just was like drilled into our head that water is a better leaving group than pure acid or pure base. I don't really know” (2nd interview). The why was taught by the instructor the first time the concept was delivered; however, in subsequent presentations, these details were not made as explicit. Similarly, Marianne, declared, “Because the oxygen, I don't know exactly, I just know that it gets protonated 'cause this is more like, I think it's more like that. No, it's not. I'm not sure, I just know it does” (2nd interview). Repeated declarations of “I don’t know”, when asked why, is an indicator that the individual prioritizes surface approaches (Chin & Brown, 2000). Classroom observations showed that the instructor did explain the deeper reasoning (e.g. partial charges, stability of conjugate base, etcetera) the first time it was presented; as the course progressed the ‘whys’ were not as detailed. Formative assessment in the form of clicker questions was utilized at several points during each class period and during the weekly recitation sections.

Leonie also exhibited a surface approach to learning by her inability to make connections when prompted and when asked how she prepared for exams:

I usually study by doing those problems and then if there’s something I don't get instead of getting help from someone else, I try to figure it out on my own, and if I can't figure out, I'm like, ‘Okay that's fine, I'm just not gonna know it.’ (1st interview)
This ties in with how Leonie went about avoiding unknown problems and using visual features to make educated guesses in response to an assessment item during the second interview: “I'm just bull crapping it... I know that O and Cl are very electronegative, so I just swapped them.”

Focus on task completion, versus understanding, is indicative of a surface approach. Organic chemistry tasks often translate into “drawing the picture” correctly (Grove, Cooper, & Rush, 2012). When asked why he drew a mechanism in a particular way, Casper stated, “I've been copying the mechanism down on papers, trying [to] remember the nuances of 'em and all that crud... It just was not sticking for the life of me” (2nd interview). Explaining why electrons move in a specific way, though, is a critical learning outcome of the organic chemistry curriculum (Bhattacharyya & Bodner, 2005).

Ingrid revealed that her tutor would go over the lecture slides and she would occasionally ask questions. The tutor would probe her understanding and she would try to explain. However, when questioned during the second interview why she did not ask more questions, she stated being uncomfortable and not wanting to appear “dumb” in front of peers or the instructor:

I also hate going to ask questions 'cause I feel like it makes me look more stupid than I really am... Also in class, in [recitation], I hate to ask questions cause I don't wanna sound stupid. A lot of my questions I have is, I really don't understand what's going on and I don't wanna ask people be like, 'Why she asking this? We just went over this in class.' 'Cause I find myself, doing that to other students, but I don't wanna be that person.

The amount of material covered in the organic chemistry course was frequently cited as a rationale for resorting to more surface approaches to learning. Casper declared,

I can tell the main part [of why I got a low score on my exam] was just because the memorization was what killed me. I just couldn’t keep up with all the [expletive] I had to memorize; you know? (2nd interview)
Similar rationales for the approaches used by organic chemistry students have also been reported (Anderson & Bodner, 2008; Grove, Cooper, & Cox, 2012; Bodner & Weaver, 2008).

**Deep Learning**

Deep approaches to learning contrast surface approaches, wherein a learner engages in a process of making connections between ideas, between what they have learned and what they are learning, exhibiting metacognitive behaviors, and persisting in their studies (Chin & Brown, 2000). When our participants were asked how they approached learning in non-organic chemistry courses, all reported using memorization as a primary approach and rarely made connections or related material to other classes. Seven of our participants (Annette, Ashe, Claude, Dimitri, Edelgard, Lysithea, Petra) described deep approaches to learning when studying for their organic chemistry course and evidence of those approaches emerged through how they responded to the problems presented in the interview.

Recognition that one’s approach to learning is insufficient is characteristic of deep approaches to learning. The locus of change can be internal or external; irrespective of locus though, improving and constantly evaluating one’s approach is critical. Dimitri, for example, engaged in a conversation with the course instructor that served as a call to change:

I think, for the third exam I was a few days out and I went up to [the instructor] and I’m like, Hey, I’m like, ‘This is getting to be a lot of reactions. Is there a way to memorize it?’ And anyone who knows [the instructor] when he gives you that sassy look, you’ve done [expletive] up... And he literally gave me that look, and he’s like, ‘It’s not about memorization.’ And I was like, let me think about that and I was like, ‘it’s literally the same concept…’ And so I looked for common themes..., oh that’s literally the same concept... and I think that was the aha moment. (2nd interview)

While the course instructor had told students throughout the semester to not study through memorization, this interaction was ultimately impactful in changing Dimitri’s approach. However, while
the instructor told students not to memorize, the instructor did provide review guides which students mentioned as a ‘memorization checklist’ as it lacked detailed explanations that the instructor intended the students to fill in on their own.

Making connections between reaction mechanisms is a means to move away from memorization. Ashe mused during the first interview, “I guess it started to feel like what [reaction mechanism] isn't an acid-base reaction then 'cause everything has to do with electron transfer is like, that happens in every reaction then what isn't an acid-base [reaction]?” Continually seeking patterns between concepts suggests a deep learning approach.

A key affective characteristic of deep approaches is persistence. This is in contrast to the surface approach in which a learner will give up more easily. Annette offered her method:

If I get too frustrated on problem, I'll just start crying and then I won't do it, but I'll keep trying to do it, and that just makes it worse, because I'm not going to be able to figure it out if I'm frustrated and then I'll just stop studying for the whole day and that's not good either. And just tell myself to pull it together and just you're having problems just don't try to keep working on it, put it aside, do something else, come back to it, it'll probably make more sense after you spent a little time disengaging... (1st interview)

Annette recognized that stepping away from the task was beneficial but noted returning to the task was necessary. Learners utilizing surface approaches rarely return to the task.

Students regardless of surface or deep approaches could still understand that organic chemistry was different in the overall amount of material. During the second interview Casper noted, “Organic chemistry is one giant build up though. So, I guess that everything is interrelated when you think about it;” thus, as Casper experienced, not returning to challenging material can have a large impact on performance in the course.
Deep learners also recognize areas of weakness and lack of understanding, key to metacognition. Learners using a deep approach focus on deficiencies rather than avoid them:

So, I was able to then identify, what concepts I absolutely didn't understand so when I went back to the book to get the few practice problems that I did, it was like hitting on my weakness instead of hitting on my strength. (Dimitri, 2nd interview)

Figuring out what was missing in his understanding was also important to Dimitri:

I'm good at working through it and figuring out how to get to the right answer and so I think that that struggle helps me in. Yeah, it might take a little bit longer, but it helps knowledge actually stick versus if I was just told or shown it by a TA that I might have this false equivalency of knowledge where I'd be like, "Oh yeah, I get it." And the next day I'm gonna do on my own. I'm like, "What was that?" (2nd interview)

This is an example of a deep approach, wanting to discover meaning by oneself as opposed to memorizing an overly simplistic and unnuanced set of rules.

Deep learners also describe talking out loud to themselves while they work through problems. For example, Annette reported: “I just read the question out loud and then say, like, okay, this is what I do first, and I don't know, I just talk through it out loud because that helps me think about it” (2nd interview). Dimitri stated that talking out loud and helping individuals who are close to, but slightly lower than, his level of understanding had similar benefits:

It's why I like philosophy, 'cause you get to talk through ideas; if I don't do the same thing with science, I don't do well. So, what I've done is either I tutor somebody that's a little bit below my level as far as grades and I try to bring them up or I talk to myself and so I've kinda tried both of those things. And they worked similarly. (2nd interview)
The surface-deep framework suggests that richer, detail-dense explanations when solving problems is indicative of a deep learning approach. When Petra was prompted to explain an acid catalyzed $S_n1$ reaction in the second interview, she offered this response:

So there's a lone pair on the oxygen first, and then there's a hydrogen. So, OH, is a poor leaving group. So, it's gonna protonate and take that hydrogen from the H and then it's gonna become water, and that's a good leaving group, 'cause it's a weak base and then the leaving group is gonna leave its tertiary. So, you're gonna form a carbocation as your intermediate and then you've got a Cl minus with a lone pair. And that's attracted to the positive. So then that does that, and then because it's a tertiary it's a carbocation, and it can do a front side or backside attack.

Petra invoked an illustrative and causal-type reasoning in describing the reaction, noting stability of intermediates, likelihood of the leaving group, and recognizing the three-dimensionality of the product. Richness of explanations is linked to more implicit problem features, such as areas of electron sufficiency and deficiency in reactants, intermediates, and products. Claude noted in his explanation of an $S_n1$ mechanism in the second interview:

So the only way we could do that is to protonate this. And then you would have water. Then you have Cl minus over there. Cl minus is a halogen with a negative charge and this [tertiary carbon] is very hindered. So I feel like [water] would leave first 'cause [Cl-] is not gonna want to attack [tertiary carbon], [Cl-]'s a strong nucleophile. But like, I don't think it's gonna just attack straight away in an $S_n2$ fashion. And then it's gonna leave a carbocation which is favored and then that's gonna attack it and then you get that since there's no stereocenter because this is a methyl it's just gonna be in the plane.

Cruz-Ramírez de Arellano and Towns (2014) highlighted warrants (Toulmin, 1958) as critical to understanding organic chemistry reactions; warrants (i.e., how data leads to a claim) show deeper
understanding. More detailed explanations are evidence of meaningful (Grove, Cooper, & Cox, 2012) and more mechanistic-oriented learning (Galloway, Leung, & Flynn, 2018).

**Individual Studiers**

Ten of the participants (Annette, Bernadetta, Casper, Dimitri, Dorothea, Edelgard, Leonie, Lysithea, Marianne, Petra) described their study approaches as individualistic, preferring to study alone. Group studying was considered distracting and unproductive:

> I studied best by myself. Honestly, I get distracted if I'm with other people, and I study best in my room, I know some people study best when they're a library with other people, I just like to be alone. (Marianne, 1st interview)

Social anxiety was noted as a reason to avoid working with others. Leonie reflected on an experience studying for organic chemistry “…it kind of felt awkward asking [a fellow student to study] again...What if they don't wanna talk to you, and they wanna just politely reject you?” (2nd interview). Additionally, for participants who found themselves learning the material quickly, they resisted studying with others as they would be expected to tutor and take time “explaining something to someone else that I [already] understand” (Petra, 2nd interview); this was considered “wasting time.” However, some found a collaborative approach helpful:

> I kept getting together with my friend... right before the exam, he’ll get with me and he’ll have me tutor him through everything, so in doing that and explaining it, it was impossible to get him to memorize reactions. So I had to, like I do peer leading. Ask him why he did what he did, get him to understand the concept and then that helped me understand it and I think that's why I did so well on exam four. (Dimitri, 2nd interview)

In Dimitri’s reflection, he discussed his experience serving as a “peer leader” for the general chemistry course sequence at the research setting; peer-led team learning (PLTL) is an active learning, workshop-based pedagogical strategy (Gosser et al., 1996). All sixteen participants experienced PLTL in one or both
of their general chemistry courses. A byproduct of the PLTL experience is that students may see the value of collaborative learning and seek out future collaborative learning experiences (Tien, Roth, & Kampmeier 2002); given that only six participants sought such collaborative learning experiences in this subsequent organic chemistry course, such a byproduct of PLTL does not appear to be fully realized with this sample.

**Collaborative Studiers**

Six participants (Ingrid, Hilda, Mercedes, Sylvain, Ashe, Claude) reported studying with peers for their organic chemistry course. One of those participants, Ingrid, reported studying with peers met through their PLTL experience in general chemistry:

> I did the gen chem 1 group, I did, and we still talk, some of us are still in orgo. So, we still study now, so it is kinda helpful in that sense, where I can still connect with my people and be like, ‘Okay how did you guys learn it or what are you guys on?’ And then we go, able to help each other if we are ahead or behind or whatever. (1st interview)

However, when asked about this collaborative approach in the second interview, Ingrid reported that she had replaced her group study sessions with weekly tutoring sessions.

Two participants, Ashe, and Claude reported forming study groups after meeting students in the tutoring center; for clarification, Ashe and Claude were not in the same study group. Their study groups, however, approached studying in a similarly structured way:

> We all get together and then we'll decide on some material to work on whether it be textbooks exercises or old exams... We’ll decide on what to do and we'll all do it together. ...after each question, what did everyone get? Like a Socratic seminar type thing, what did everyone get? Then we talk about it, see if we got someone who got it right and whoever got it right would explain to the people who got it wrong and why or what thought process went through to get to that answer. (Ashe, 2nd interview)
The “Socratic” method discussed by Ashe suggests that the group’s study process was not focused on one person “teaching”, but fluid in terms of who was helping who. The process reported by Ashe is also indicative of metacognition, wherein the group was facilitating each other’s reflection on what they know and do not yet know. Ashe also reported that he did not engage with his study group until after the first organic exam when he realized that his previous studying approaches were not as successful as he had previously thought.

Claude learned about the tutoring center after his first semester of general chemistry; he actively looked for people to study with and had a dozen or so people who he would regularly study with. Claude was unconcerned about needing others to teach him:

I generally like to find someone who was a lot smarter than I am, like very much and then I feel like an idiot and then I feel like I have to compensate for that...I don’t do it in class 'cause I feel like every time I’ve generally felt like an idiot cause I’ve asked a few questions, and I generally felt like an idiot the whole time so that’s cool. But I rather just do it in [the library] 'cause at that point, we all feel like idiots so it’s fine. (2nd interview)

He was comfortable asking for help outside of the classroom, because he felt that everyone who he was working with was there because they also recognized their need to get help.

Hilda offered a different perspective, perceiving collaborative studying being helpful and unhelpful. Hilda switched study partners after the first exam because they had different instructors. When Hilda was asked about who she studies with for organic chemistry, she noted different study partners offered different experiences: “[PARTNER-1] tends to know more. So, I tend to ask her more questions, than she'll ask me. Where I was with [PARTNER-2]. I'll teach her stuff more than she'll teach me. Which would be, then, different yeah” (2nd interview).
Each of these six participants maintained a collaborative approach throughout the course, finding that even when the composition of study groups and sources of assistance needed to change, studying for the course individually was not preferred.

**Combining Approaches to Studying with Evidence of Understanding**

The overlap between the surface-deep and individual-collaborative frameworks provides a nuanced perspective on preferences for how participants approached learning. Participants were categorized based on articulated study approach preferences (see Table 3.2 above).

Five participants (Bernadetta, Casper, Dorothea, Leonie, Marianne) were characterized as having surface understanding and individual approaches. These participants distrusted working with others in that a collaborative approach might not help them, and exhibited little metacognitive behavior, relying on limited and memorized responses to problems.

Leonie and others brought up social anxiety as a reason why they avoid working with others. Working alone was easier because of perceived judgement that might be passed on them if they were viewed as stupid. These perceptions were also directed in their avoidance of difficult concepts or engaging with the material in a superficial way by reciting and memorizing basic concepts or patterns without understanding or making connections. They believed that if the assessments were changed to multiple-choice, they would improve because the amount of memorizing would be decreased, and answers could be easier to produce. However, the four midterm-exam scores for these participants trended downward across the term suggesting that the individual studying approaches contributed to a decreased performance.

Five participants (Annette, Dimitri, Edelgard, Lysithea, Petra) were characterized as utilizing deep and individual studying approaches. These participants reported engaging in self-assessment with limited external help. Many expressed being tired of being the only student working during group activities; these participants acknowledged that working with others could be a useful technique, but
ultimately preferred to "study" with others as a means to testing their knowledge by “teaching” others, which are behaviors not inherently collaborative. One unique finding that emerged from this group was that each student mentioned competition as a motivating factor for their success. Lysithea commented on her motivation:

Yeah, it's more like I need to study for this or I'm not gonna do well on the test, which I obviously need to do well, so I can have the competitive application for pharmacy school. That's probably most [of] the motivation. (1st interview)

This motivation was also what lead Dimitri to approach the professor and have a meaningful conversation about studying and not memorizing. Midterm exam scores for these participants were above average, often by 20+ points, across the term.

Four participants (Hilda, Ingrid, Mercedes, Sylvain) were characterized as understanding from a surface approach, but with a collaborative studying perspective. Despite engaging in collaborative studying, these participants changed from being with individuals of similar understanding to working with individuals who had a better grasp of the material. Both Hilda and Ingrid saw a lowering of her exams after switching from a collaborative group of similar abilities to being tutored by individuals. Surface learning was evidenced by these individuals, such as when probed regarding why water is a good leaving group; it was simply a fact that they had been told repeatedly. As with participants who evidenced surface understanding and stated individual studying approaches, these participants’ midterm exam scores trended downward.

Two participants (Ashe, Claude) were characterized by their deep explanations and collaborative perspective. These participants expressed their willingness to seek out help and be vulnerable in expressing their misunderstandings. Socratic, dialogue-based learning was key as they actively sought people with whom they could study. They also utilized warrants and asking deep questions when they
engaged with the problems presented. These participants maintained above average, and relatively consistent mid-term exam scores.

Discussion

Approaches to studying espoused by organic chemistry students outside the classroom appear to be associated with performance in the course. We found evidence of students exhibiting four approaches to studying from the two models: surface, deep, individual, and collaborative. Approaches arose from the prior success of the approach. Many had an understanding that studying with others was not ideal because doing so was potentially distracting. Also, participants expressed that collaborative studying was simply individuals being taught, instead of a collective experience. Yet, some found a collaborative environment, characteristic of Socratic learning, helpful in their studies. Lastly, the types of assessments (e.g., free response) were considered a cause of difficulty in the course by our participants. In particular, our interviews were modeled as assessments of organic chemistry knowledge and skills that required drawing pictures and providing explanations. Responses to such assessments noticeably differentiated students who engaged in more surface versus deep learning approaches.

Our results underline an affective component to preferred studying approaches, namely avoidance of difficult material and avoidance of demonstrating folly in front of peers. Such avoidance behavior was not prohibitive in non-organic chemistry courses, and thus participants were surprised when such behavior did not lead to similar results in organic chemistry. Students who were unwilling to demonstrate a lack of understanding by asking questions found themselves behind as the course progressed. Social anxiety, such as with Leonie, appeared to drive students’ unwillingness to engage in more collaborative learning even with peers who presumably are having similar difficulties. Students with a deep approach reported persisting in their engagement with the material, sometimes after a brief break from studying, but committing to the task regardless of difficulty or frustration associated with their lack of understanding.
An initial driver of our study was the thought that students’ prior experiences in PLTL chemistry course experience would lead to more spontaneous collaborative learning approaches. While participants discussed their PLTL experiences, in part due to prompting, our participants did not corroborate the expectation that such students would spontaneously seek future collaborative learning experiences (Tien, Roth, & Kampmeier, 2002). Our results indicate that students desire to collaboratively study stems more from a personal choice or preference than from a structured past experience. There is an opportunity to change the mindset of students to perceive the benefits of collaborative learning as a developable skillset.

While we envisioned that surface-deep and individual-collaborative approaches would be associated with performance, our data suggest the surface-deep model was more informative. This resonates with our experiences as instructors. While our results are assuredly not predictive, nor quantitative in nature, our results do mirror findings that surface approaches limit potential performance: Tomanek and Montplaisir (2004) concluded that first-year biology students were unable to approach their learning in deep ways because they had little experience doing so. Students in their course commented that the resources and operations they used to study for exams are similar to what we found: students either did not 1) know how to study for meaningful learning, or 2) felt that a new approach was necessary in order to be successful on the test. Sinapuelas and Stacy (2015) found a correlation between study approaches and exam performance showing that few students reached the highest approach level of application-based approaches towards the end of the course. Prosser, Walker, and Millar (1996) found a large number of first year physics students reported primarily using surface approaches to learning. Collaborative learning has been touted as a necessity to help increase retention in STEM, especially for minoritized students (Olson & Riordan, 2012). We hypothesized that due previous experience with collaborative learning (i.e., PLTL) that our participants would be inclined to use collaborative learning strategies in organic chemistry; this is similar to a finding by Van Vliet, Winnips,
and Brouwer (2015), who found that biology students who had participated in collaborative learning pedagogies were no longer engaging with each other after five months.

What is surprising is the lack of importance that was attributed by the participants between individual-collaborative approaches and performance. An investigation of mid-term exam performance suggests that the surface-deep model was more informative. Socially constructivist-based learning, though, is touted as extremely beneficial to learning (Wilson & Varma-Nelson, 2016; Tang, 1993; Christian & Talanquer, 2012). We believe that a lack of meaningful collaborative approaches stems from a lack of understanding of how to utilize and benefit from such an approach. With less than half \( n = 6 \) reporting consistent collaborative studying, it is evident that effective collaborative studying needs to be better understood in order to have larger influence on the studying for the course.

**Implications for Practice**

The key implication for practice is the need for instructors to model ideal collaborative studying behaviors during class sessions through possible role playing or by highlighting good didactic questioning when the professor or teaching assistants perform such actions. The instructor should provide means for students to meaningfully engage in learning with peers by setting up study groups that students would be required to work with throughout the semester. We concur with Anderson and Bodner (2008) that it is a mistake to assume that students know how to approach learning organic chemistry based on their performance in general chemistry. However, we would more parsimoniously state that it is a mistake to assume that students know how to approach the learning of organic chemistry, period.

The central tenet of most reformed organic chemistry curricula is making the “why” more apparent (e.g., Flynn, & Ogilvie, 2015). Eloquent oratory of these explanations is not enough to promote learning (Deslauriers, McCarty, Miller, Callaghan, & Kestin, 2019). The process of constructing explanations must be modeled; the process of explanation construction, more importantly, must be done by the learner. Students who embraced a deep learning approach repeatedly discussed the
importance of talking out loud when working on problems. Worked examples wherein the thought processes, and even intentional mistakes are made, can be demonstrative to developing explanatory skills; however, there is a possibility that too many worked examples would further catalyze surface learning through memorization of all possible explanations. As Trigwell, Prossor, and Waterhouse (1999) found, more student-centered approaches enacted by the teacher lead to more deep approaches embraced by students.

Collaborative learning is key to creating a student-centered learning environment. Our study had two principal examples (Ashe and Claude) who studied collaboratively with deep learning, their exam grades were above average and consistent. However, they are a small sample. A majority of students’ lack understanding of how to form and participate in effective collaborative learning groups outside of the classroom. Christian and Talanquer (2012) found that group work was commonly focused on solving problems provided by instructors and that studying through solving exam-like problems was the main study strategy used by their observed groups. For many students, collaborative learning translates into “completing homework” or other assignments in the presence of other students; whereas true collaborative learning creates space for students to challenge and support each other in the learning process. Questions are asked of the course material, and questions are asked of each other. Students are rarely “shown” what such learning looks like; more explicit instruction on collaborative learning is necessary. Class period time (or other course-related time such as recitation sessions) could be devoted to showing examples of how best to collaboratively study. Demonstrating a didactic learning interaction where an individual is asking why in response to another problem solving could help get across the idea that collaborative needs to be a conversion. Suggestions for how to structure the collaborative learning experiences, including methods for going through the course material, metacognitive questions to ask each other, etc., could be modeled and provided to the students.
A culture that embraces question asking and productive failures is essential to student success. We recognize that saying “it’s okay to make mistakes” is easily said. We recognize that mistakes are integral to learning (Kapur, 2008). Simple choices can be beneficial like creating a more inviting space for students to be themselves and share their misunderstandings by moving office hours to a library, campus dining hall, or a local coffee shop, rather than a faculty office, conference room, or classroom space. Kapur (2008) suggested that the inclusion of ill-structured problems (i.e., problems that require definition, constraints, and collection of data) lead to better performance on well-structured problems. Creating homework assignments that require thought and engagement with the material, and that advantageously benefit students who do collaborative work, can be beneficial. Interaction with the course instructor may create a culture where students are more likely to embrace their fear of not knowing and seek out knowledgeable others.

Implications for Research

We offer two specific implications for research. The first is to evaluate the quantitative association between approaches to learning and performance in organic chemistry. Bunce et al. (2017) reported general chemistry students’ use of surface and deep approaches by final course grade; suggesting a predictive, potentially non-linear relationship between learning approaches and course performance. Our data suggest that a quantitative investigation would provide a new layer of understanding as to why students perform as they do in organic chemistry courses. We should note that how surface-deep approaches are defined (and how ‘measures’ are developed and evaluated) will influence the results of such a quantitative study. Bunce et al. (2017) utilized a Modified Approaches and Study Skills Inventory; wherein, analogous studies outside of chemistry course contexts have utilized a number of instruments, including the Revised two-factor Study Process Questionnaire (Biggs, Kember, & Leung, 2001), the Learning and Study Strategies Inventory (Weinstein, Palmer, & Schulte, 1987), and the Motivated Strategies for Learning Questionnaire (Pintrich, Smith, Garcia, & McKeachie, 1993).
The second implication is the need for targeted intervention studies focused on study habits/approaches to learning. For example, how does more explicit instruction on constructing the “why” for organic chemistry concepts and skills impact students’ approaches to learning? Additionally, how does explicit instruction on how to construct and engage in collaborative learning impact students’ approaches to learning? Proposed interventions focus more on student behaviors rather than performance, albeit behaviors associated with performance.

Limitations

There are three key limitations to our study. First, students self-selected to participate and may not be representative of the course. Nevertheless, we found instances of each learning approach and performance trends. While we cannot commit to what percentage of students use each approach, we can assert that our participants were found to exhibit behaviors associated with all four approaches. We recommend a more quantitative study to further investigate prevalence and how strongly each learning approach is associated with performance.

Second, our data are self-reported. While Author Clark did observe class periods, we did not observe participants while they studied for the course or in their preferred context(s). The use of two interviews with a member check, class period observations, think-aloud problems, and exam scores provided a means to triangulate our data; however, we are unable to discern between actual and reported learning approaches. While such data would be informative, we concur with Christian and Talanquer (2012) who lamented that observing study groups was difficult because of continuously changing groups, dynamics, time, and location of meetings, etc. We, also, acknowledge that asking students to report prior and current performance (i.e., course and examination grades) and approaches to learning in prior courses and non-organic chemistry courses may introduce unwanted stereotype threat. An observation-based study may have minimized such threat; however, new limitations (e.g., being watched) would be introduced.
Finally, we acknowledge (and caution others) that our labeling of each participant as exhibiting a particular approach to learning does not encapsulate the nuances and complexities of learning. An approach to learning is not a characteristic of a learner, but an engaged process at a given time. In different contexts (for example, non-chemistry courses), participants reported using different approaches to learning. We have thus been purposeful to limit our use of the terms “surface learners” or “collaborative learners”, as approaches to learning are not identities. We, however, report consistent approaches to learning used by our participants in the target course, and thus have accordingly been able to provide such a “label” that has been informative in thinking about learning in the specific context of a postsecondary organic chemistry course.

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Chapter 4
Perceived roles of peer-leaders: An exploratory study in a postsecondary organic chemistry course

Note to Reader

This chapter is a published manuscript in the *International Journal of Teaching and Learning in Higher Education*:


This work was published with a co-author. Jeffrey R. Raker is the principal investigator for this project.

Abstract

Peer-led team learning (PLTL) is a pedagogical method in which former students, i.e. those who have successfully completed the course, assist current students in learning course material either through supplemental instruction or in the classroom setting. The impact on student learning for students participating in a PLTL course is widely documented; however, there have been few studies about peer leaders’ experiences and the impact of PLTL on peer leaders. Fifty-two peer leaders assisting with a postsecondary organic chemistry course completed weekly journals about their experiences; the final journal entry prompted peer leaders to describe their relationship with their students by choosing a role that best described that relationship and providing an example of how they filled that role during the term. These entries were coded and analyzed for patterns. Results suggest that when peer leaders describe their relationships, some express they are teachers, others consider themselves guides or facilitators, and some view their role as a mentor. We argue that there is a progression of increasing
depth in the student-leader relationship that is demonstrated by the description of the roles ascribed by the peer leaders.

**Introduction**

Peer-led team learning (PLTL) is a pedagogical technique used to improve student learning through the use of peer leaders to assist students in learning course content and skills (Hockings, DeAngelis, & Frey, 2008). PLTL is built on a constructivist theory of learning as informed by Vygotsky (1978). Peer leaders, i.e. students who have successfully completed the course in which they are assisting, are assumed to have a good understanding of the gaps in student understanding and how to fill those gaps. Thus, peer leaders can assist in identifying zones of proximal development for students and provide the necessary support to catalyze learning (Cracolice, 2012). PLTL has been shown to have particular success in increasing conceptual understanding (e.g., Smith et al., 2009). Research on the efficacy of PLTL has mainly focused on student learning and engagement (e.g., Chan & Bauer, 2015; Drane, Smith, Light, Pinto, & Swarat, 2005; Hockings et al., 2008; Mitchell, Ippolito, & Lewis, 2012; Tenney & Houck, 2003); much less research has focused on the peer leaders and their experiences (e.g., Brown, Sawyer, Frey, Luesse, & Gealy, 2010; Gafney & Varma-Nelson, 2007; Hug, Thiry, & Tedford, 2011; Snyder & Wiles, 2015; Tenney & Houck, 2004). Our study is focused on the latter and considers the roles in which peer leaders perceive themselves as enacting during peer leading sessions. Our work provides a framework for developing and refining whole group discussions and reflection activities for peer leader training programs. The roles that some peer leaders as having are different than what the PTLLT literature sets as the ideal or standard. The role of mentor is mentioned in PLTL literature as a possible side effect but not the key role of the peer leader (Gosser et al., 2001). By examining the reflections of peer leaders who both choose this role mentor, or choose a different role, a theme of personal involvement emerged. We use this theme to argue for a potential pathway of deepened student-peer leader relationships.
Literature Review

Peer Mentoring

Mentoring has been a concept that many people have tried to define. Jacobi (1991) stated that “although many researchers have attempted to provide concise definitions of mentoring or mentors, definitional diversity continues to characterize the literature” (p. 506). Merriam (1983) stated:

The phenomenon of mentoring is not clearly conceptualized, leading to confusion as to just what is being measured or offered as an ingredient in success. Mentoring appears to mean one thing to developmental psychologists, another thing to businesspeople, and a third thing to those in academic settings. (p. 169)

Thus, defining mentoring in the context of research is critical. With this in mind, we use a definition of mentoring as articulated by Kram (1983).

Kram (1983) argued that mentoring is the relationship between a senior or more experienced individual (known as the mentor) and a junior individual (known as the protégé). The relationship serves two functions: The first is that the mentor gives advice or guidance about development behaviors that can lead to success in the protégé’s choose field. The second function is personal support. This can come in the form of socialization or emotional support, known collectively as psychosocial support (Kram, 1983; Bozeman & Feeney, 2007; Eby, 1997). Informal and formal mentoring has been shown to have positive outcomes in both career and professional development (e.g., Campbell & Campbell, 1997; Chao, Walz, & Gardner, 1992). It has been shown that individuals with informal or formal mentors had improved socialization, satisfaction, and salary (e.g., Chao et al., 1992) and improved GPA and retention (e.g., Campbell & Campbell, 1997) when compared to individuals without mentors. Zachary (2002) stated that “teachers who prepare themselves as mentors increase their potential to enhance student growth and development, help students maximize education experiences, and enrich their own teaching
experience and professional development” (p. 27); preparation to be a mentor is associated with higher potential for a positive impact on the mentee.

Mentorship of students by peer leaders has observed in the context of PLTL (Gosser et al., 2001); however, the extent to which mentoring occurs nor mentorship training for PLTL peer leaders has not been documented in the literature. Research on mentoring shows that formalized and explicit mentorship training has an effect on achievement in postsecondary courses and persistence in postsecondary degree programs (e.g. Becvar, Dreyfuss, & Dickson, 2008; Colvin & Ashman 2010). In the context of non-PLTL settings, peer mentorship programs have been shown to increase retention (e.g., Damkaci, Braun, & Gublo, 2017), a desired outcome of PLTL efforts. Peer leading sessions provide an ideal context for mentorship, as described by Buntinga & Williams (2017), namely that meaningful engagement in a learning environment is advantageous for peer mentorship. Peer leaders, having previously taken the course as students, are ideally situated to provide mentorship. This kind of mentorship, as articulated by Colvin & Ashman (2010), can be in the form of answering questions on what future classes to take, which professors are preferred, how to properly study for the current class, how to get more involved with undergraduate research, and how to become a mentor in the future; Colvin & Ashman (2010) were focused on peer mentors for a First-year University Student Success class that was designed to mentor students through their first year of college.

**Peer-Led Team Learning - Pedagogy and Student Learning**

Peer-led team learning is a pedagogical strategy that pairs a peer leader with groups of three to four students for the purpose of completing an instructional activity (e.g., end-of-the-chapter problems or guided-inquiry worksheets; Gosser et al., 1996). Peer leading sessions are typically held once per week for the duration of the term; sessions can be held as optional activities outside of scheduled course times (e.g. Chan & Bauer, 2015), during scheduled recitation or help sessions (e.g. Tien, Roth, & Kampmeier, 2002), or replacing scheduled classroom time (e.g., Robert, Lewis, Oueini, & Mapugay, 2015).
Students participating in courses with PLTL are shown to have increased achievement (e.g. Drane et al., 2005; Hockings et al., 2008; Mitchell et al., 2012; Stewart, Amar, & Bruce, 2007; Tenney & Houck, 2003); researchers have found that PLTL has a positive impact on underrepresented students and at-risk students (e.g., Drane et al., 2005; Stewart et al., 2007). PLTL has been found to be an effective pedagogy in an array of disciplines and learning environments (Wilson & Varma-Nelson, 2016).

In their review of over 67 published studies on peer leading Wilson & Varma-Nelson (2016) found a variety of undergraduate disciplines using the PLTL method including: general chemistry (Mitchell, Ippolito, & Lewis, 2012; Lyon, & Lagowski, 2008; Lewis, 2011; Chan & Bauer, 2015; Hockings, DeAngelis, & Frey, 2008); organic chemistry (Rein & Brookes, 2015; Wamser, 2006; Tien, Roth, & Kampmeier, 2002); allied health, which is also called GOB (Akinyele, 2010); introductory biology (Peteroy-Kelly, 2007; Drane et al., 2005); anatomy and physiology (Finn & Campisi, 2015); bioinformatics (Shapiro, Ayon, Moberg-Parker, Levis-Fitzgerald, & Sanders, 2013); mathematics (Reisel, Jablonski, & Munson, 2013; Flores, Becvar, Darnell, Knaust, Lopez, & Tinajero, 2010); computer science (Horwitz et al., 2009); engineering (Johnson, Robbins, & Loui, 2015); psychology (Miller, Amsel, Kowalewski, Beins, Keith, & Peden, 2011); and physics. (Drane et al., 2005). This plethora of STEM disciplines gives reason to understand how to this pedagogy is effecting the peer leaders themselves since they are coming from so many different disciplines.

**Peer-Led Team Learning - Peer Leaders**

Peer leaders are typically selected based on success completing the course for which they are peer leading. Compensation varies based on course and institutional context, with peer leaders receiving class credit, hourly wages, or letters of recommendation for professional and graduate school as remuneration (Gosser, Kampmeier, & Varma-Nelson, 2010). Training programs range from one day to week-long workshops before a term begins, or weekly workshops during the term. Peer leaders are defined as facilitators throughout PLTL literature (e.g. Gosser et al., 1996; Hockings, DeAngelis, & Frey,
Training is focused on facilitating learning, facilitating group work, and refreshing course content and skills (Kampmeier, Varma-Nelson, & Wedegaertner, 2000). Weekly workshop training formats are typically modeled after the peer leading sessions with the instructor of the course acting in the role of the peer leader, and the peer leaders acting in the role of the students.

There are limited examples of PLTL researchers using journal entries of the peer leaders to examine the personal experiences of those peer leaders. Using journals, leaders can learn from their experiences through retrospective reflection (Boud, 2001). Boud goes on to state that reflective thinking is not simply a process of thinking, but one that involves feelings, emotions, and decision-making to identify important events and analyze the significance of these events. Johnson, Robbins, & Loui, (2015) looked at journal entries of how chemistry peer leaders self-reflected about their peer leading experience. Within fourteen journal entries, they found few mentions of peer leaders that stated that they found fulfillment from helping others, and no mentions of a leader expressing a feeling of obligation to help others. Johnson, Robbins, & Loui, (2015) theorized that this was because their peer leaders may have been too focused on the mechanics of facilitating individual team meetings to recognize the broader implications of their actions on their students. By focusing our self-reflection journal entry prompt on perceived roles, we hoped to see examples of how the peer leaders’ interactions with students were exemplified.

Facilitators and mentors are two distinct yet overlapping roles from which to consider peer leaders. From a broad, overarching perspective, these two roles lead to different peer leader-student interactions and thus theoretically two different learning experiences for the students. Colvin & Ashman (2010) found that in the context of a first-year peer mentoring program the roles peer mentors perceived themselves as enacting had an impact on the types of relationships the peer mentors had with their students.
While facilitator, guide, and mentor are roles that are identified in the PLTL literature (e.g. Gosser et al., 1996; Hockings, DeAngelis, & Frey, 2008; Kampmeier, Varma-Nelson, & Wedegaertner, 2000), we conjecture that peer leaders could perceive themselves in other roles including teacher, instructor, coach, or advisor, for example. We are interested in identifying the roles peer leaders perceive themselves as enacting in the contest of peer leading. Through an understanding of these roles, peer leader training programs can be refined to promote more meaningful student learning and more impactful experiences for the peer leaders and students.

Research Questions

We sought to answer these questions through our study:

RQ1: How do peer leaders view their role in the context of peer-led team learning?

RQ2: How are these roles related to the peer leaders’ self-reported interactions and relationships with their students?

Methods

Our study was conducted in the Fall 2015, Spring 2016, and Fall 2016 academic terms at a large research-intensive university in the southeast United States. Peer-led team learning was incorporated into half of the lecture sessions of the first semester of a yearlong postsecondary organic chemistry course. Content instruction was provided via a flipped-classroom approach using online videos (c.f., Robert et al., 2016). Peer leaders received weekly training on a worksheet activity that the students would complete, common misunderstanding and mistakes made by students, and how to promote learning. Teaching assistants for the course ran 50-minute weekly recitation sections on Fridays in addition to the lecture sessions. These teaching assistants were graduate students and were also responsible for proctoring and grading exams outside of set class time and had limited interaction with the peer leaders. The course and peer leader training sessions were taught by the same faculty member for all iterations of the study. Peer leaders completed weekly reflective journal assignments following
each peer leading session; the last assignment focused on the peer leaders’ perceived role. Peer leaders received college credit for their peer leading training course and were only allowed to be a peer leader once.

**Participants**

A total of 52 peer leaders participated in the course over the three iterations. Each iteration had approximately 240 students enrolled in the course. The peer leaders (16 to 18 per iteration) were assigned three to four student groups, giving each peer leader responsibility for about 12 to 15 students total. Peer leaders were compensated with junior-level chemistry course credit and the opportunity to receive a recommendation letter from the peer leading coordinator.

**Data Collection**

After each peer leading session, peer leaders completed a reflection journal entry that included an explanation of areas of ease and difficulty for the students in completing the worksheet, identification of insights about student learning gained by the peer leader, and an evaluation of how well assigned small groups worked together. Weekly reflection journal assignments were graded for completion; the peer leaders were encouraged to be open and honest in their reflections on their experiences as a peer leader. The last reflection journal entry of the term asked the peer leaders to “Choose ONE (1) of the following roles you feel best describes you in relationship to the students you worked with this semester: teacher, facilitator, instructor, guide, mentor, promoter, coach, assistant, advisor. Describe one concrete example of your interaction with a student(s) that best illustrates you serving in that role.” Definitions for the roles were not supplied to the students allowing for self-interpretation. The role options mirror those enacted by teachers in environments adopting a constructivist paradigm (e.g., Gergen, 1995; Mayer, 1996) and in studies of roles espoused by peers in similar situations and contexts (e.g., Colvin & Ashman 2010).
**Data analysis**

Journal entries were coded by hand individually by the first author using an open-coding approach based on thematic content analysis techniques (Guest, MacQueen, & Namey et al., 2012). This involves reading the journal entries and looking for passages that demonstrate a theme or thought of the individual. These themes can then be compiled and for our research categorized based on the role described by the peer leader. Familiarization by reading through the data was done twice to get a sense of overarching themes. Following this, data were sorted by the roles selected by the participants. Themes such as “pointing students in the right direction” or “meeting with students outside of class” were noted based on examples provided by the peer leaders in their responses. Data were reread and reanalyzed through the constant-comparative technique (Charmaz & Belgrave, 2012). This technique involves looking back through all previous entries whenever a new theme is discovered to verify that the theme was new and should be included in the codex when coding the data. Coded data were compiled and simplified into a coherent set of themes by the roles selected by the peer leaders. Finally, themes were compared across selected roles to look for similarities and differences that the roles had for the peer leaders’ interactions with their students. Peer review was done through discussing themes and roles with colleagues who were not connected with the project but familiar with qualitative coding methods during group meetings and personal communication (Lincoln and Guba 1985, 308-9). After compiling the main themes across the set roles, twelve journal entries were randomly selected by the primary author and coded by the second author. Agreement with the proposed themes was met for those entries after initial coding and discussion.

**Results and Discussion**

Peer leaders selected and provided examples of six of the specified roles in the reflection journal prompt: assistant (n = 1), promoter (n = 2), teacher (n = 3), facilitator (n = 8), guide (n = 17), and mentor (n = 22). Data for the assistant and promoter chosen roles were insufficient to warrant discussion;
therefore, these data have been removed from our analyses. While it is possible that peer leaders could have misinterpreted the definition of the role that they selected, explanations given by the peer leaders did not contradict their role choice. Coherent themes were identified for the teacher, facilitator, guide, and mentor groups. We present a discussion of the themes by role and then argue for how these perceived roles fit a framework of increased depth of peer leader-student relationships that is informative for peer leader trainers. While some themes are more prevalent than others, it can be seen that certain roles have a richer collection of themes than others (see Table 4.1). Teachers wanted to be more of a guide to their students, guides/facilitators followed the process of teaching prescribed by using didactic or probing questioning, and mentors focused more on the psychosocial support and outside time. The last theme, ‘student preparedness and readiness for peer leading sessions’, spanned each of the selected roles; we present this theme first to situate the discussion for each role and our proposed relationship progression.

Table 4.1
Themes across perceived peer leader roles. Percentages are the percent of peer leaders within that role that had at least one code of that theme.

<table>
<thead>
<tr>
<th></th>
<th>Student Readiness</th>
<th>Want to be Guide</th>
<th>Probing Questions</th>
<th>Process of Learning</th>
<th>Psychosocial Support</th>
<th>Outside Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mentor</td>
<td>14 %</td>
<td>0 %</td>
<td>18 %</td>
<td>45 %</td>
<td>95 %</td>
<td>32 %</td>
</tr>
<tr>
<td>Guide/Facilitator</td>
<td>8 %</td>
<td>0 %</td>
<td>28 %</td>
<td>84 %</td>
<td>28 %</td>
<td>0 %</td>
</tr>
<tr>
<td>Teacher</td>
<td>33 %</td>
<td>100 %</td>
<td>33 %</td>
<td>0 %</td>
<td>0 %</td>
<td>0 %</td>
</tr>
</tbody>
</table>

Student Readiness for Peer Leading Sessions

Active learning pedagogies mandate a level of engagement and readiness of students. In particular, for flipped-classroom pedagogies, students must engage with the out-of-class content (mainly instructional videos) before coming to class (c.f. Robert et al., 2016). Peer leaders from each of the selected role groups noted that many of their students had not watched the videos prior to coming to the peer leading session. Given by a peer leader who selected the mentor role: “The most difficult
part was when students had to start learning actual reactions with reagents and products. This was very difficult because if the students never watched the videos or read ahead of time, they had no clue.” A peer leader who selected the role of guide mentioned that “A lot of students in my section had often not watched the videos.” Finally, a teacher peer leader stated that “I often noticed myself teaching the concept at the beginning of class because most of the students [sic] have not watched the videos or had no clue about the material.” Several peer leaders reported feeling obligated to spend time teaching the material: “I felt like I needed to guide them to either watch the videos, go to the book, or show them how to do the basics.” Time was used instructing instead of engaging the students in completing the problem set worksheet. There are multiple instances reported by the peer leaders irrespective of the perceived role they had in the peer leading session. PLTL trainers may consider how to best address student preparedness with their peer leaders and offer strategies for how to provide assistance to underprepared students while providing more meaningful experiences for prepared students.

Given constraints of amount time per class, the large lecture hall setting, and the number of students that each peer leader had to work with, the experiences the peer leaders had were relatively the same. Despite these constraints, peer leaders used ‘student preparedness’ as a reason for why they felt they fulfilled a particular role in the peer leading sessions.

Teachers

Three of the 52 peer leaders perceived themselves as teachers in the context of peer leading. Teacher peer leaders expressed frustration rooted in their desire to be more than just teachers. Their frustration was directed towards the preparedness of the students: “the lack of familiarity the students had [with the material they should have watched before coming to class] led to my having to act as a teacher and explain concepts to them that they should have already seen.” A teacher peer leader commented, “[I] often notice myself teaching the concept at the beginning of class because most of the students hadn’t watched the videos or had no clue about the material.” The lack of preparedness
diminished the potential of the student acquiring meaningful learning during the peer leading session. Teachers struggled to get unprepared students to a level where those students could meaningfully engage in the activities.

There was a desire by these peer leaders to be more than just a teacher. These peer leaders collectively stated that while they felt like teachers, they wanted to be more of a guide to their students: “I really wanted to be more of a guide...” “...I tried not to ‘teach’ the students the material and instead guide them through it.” These peer leaders wanted to be more than ‘givers of information.’ The teachers recognized that what they were doing was not as effective “…[I] would have been more beneficial to serve as a guide.” Teacher peer leaders felt hindered by the unprepared students.

**Guides and Facilitators**

Twenty-six of the 52 peer leaders chose guide or facilitator as the role they most espoused in the context of peer leading. Guides and facilitators are reported as a single group because of the overlap of themes between these two selected roles and because ‘guide’ and ‘facilitator’ are used synonymously in the PLTL literature (e.g., Brown et al., 2010; Johnson, Robbins, & Loui, 2015). These peer leaders noted that their job was not to teach, but to be an assistant in the learning process. Guides and facilitators understood that students could not expect to receive answers and that “students actually showed visual frustration because sometimes I would not give them answers directly or I would ask them open ended questions to get them to think for themselves.” This set up is a Socratic interaction whereby peer leaders posed questions to the students to help direct the student to more meaningful learning. Guides and facilitators felt that by answering a question with another question, the students would think more deeply about the topic and arrive at an answer by themselves.

Guide and facilitator peer leaders emphasized the process of learning, rather than reinforcing an obtained correct answer. “Knowing why they got the answer is more important than knowing what the
answer is.” “I would ask questions from the students when they presented me with their answers, such as why did you do this, why didn’t you consider this, do you remember these concepts, etc.”

Facilitating learning by having the students teach each other was a common method employed by guides and facilitators. “I point the students in the right direction... they can deviate slightly but still reach the correct answer.” The peer leaders in this group acknowledged that their roles were not to give away answers but to give nudges in the right direction and let the students do the legwork. “Most of the time students would know what they were doing, they just needed a little push.” This is how the peer leading processed is ideally enacted; fulfilling these roles would constitute a successful peer leader (c.f., Brown et al., 2010; Johnson et al., 2015).

No facilitators mentioned personal interactions or relationships with their students. They made no reference that they viewed their role as more than simply helping students learn in their 75-minute weekly interaction. From the guides there were three instances where “help students set goals” and “give advice on how to study” were mention. There was one mention of psychosocial support: “if they know a peer can get through it, so can they.” These two role categories comprised the majority of the surveyed peer leaders. Only a small fraction of this majority reported any type of psychosocial or developmental support which is to be suspected due to their choice of role.

**Mentors**

Twenty of the 52 peer leaders felt they espoused a mentor role in peer leading sessions. Mentors believed that by connecting their own experiences with the course, it would allow the students to develop a deeper understanding of the material: “I was open about my own struggles when I first took the course and I saw a difference in her [a specific student the peer leader was working with] demeanor.” Sharing personal experiences with students varied from,
[a student] told me he was having trouble with time management and feels like he is drowning in work... I informed him that I was once exactly like him and in his situation... I answered all of his questions, tried to guide him through a plan of how to get more involved.

to more friend-based interactions like when,

I had one student who broke down... due to the class being overwhelming... After talking to her and consolidating her, I began to talk to her about my experience in Organic Chemistry, what I needed to do to succeed, the dynamic of the course, how much I studied, how I studied, and introduced her to students who did understand the concepts well so they could study outside the course together.

*Mentor* peer leaders communicated their personal struggles in learning the course material and how they overcame those struggles; the *mentors’* goals were to relate to the students and help the students develop a hope-based perspective on achievement in the course.

These peer leaders shared with their students that it is possible to understand organic chemistry despite struggling: “I gave [the student] personal stories... I told [the student] how I studied organic chemistry and how many hours I would spend studying it.” Some *mentors* voiced to their students’ gaps in their own understanding of the material; instead of letting it be a hindrance, these peer leaders were willing to note their deficiencies: “...I for one didn’t know everything and even found myself making silly mistakes [when working with the students in the peer leading session] but that I also could help them learn from my experience.” This humanization of the learning process led to a sense of approachability and a level of trust and friendship that the *teachers, guides, and facilitators* did not report.

*Mentors* described instances where they created an environment where students could feel comfortable coming to them: “I made sure to set myself in the same plane as them, let them know I am a student, step off that illusion of me being a teacher and made sure that I was not condescending.” Thus, *mentors* created an environment that was about more than just learning the content and being
able to solve the problems. Building a high level of trust was important to establish for mentor peer leaders. Almost 60% of the mentors reported that they took a “personal interest in or became friends with their students” during the course of the semester. Mentors felt “personally responsible” for the success of their students.

Mentors reported looking for ways to describe how the current concepts in the course were tied into their overall educational experience and courses for their major. This approach demonstrated a substantial investment of time on behalf of the peer leader, more than what was required of the peer leader. One mentor noted that they would “review night before to be able to help teach information to students who would be lacking.” These peer leaders looked for other resources that students may not have been aware of: “I incorporated outside sources other than straight organic chemistry to enhance the learning environment.” “In addition to helping out with the problems I offered a lot of advice on studying habits and techniques.”

Some mentors reported they “stayed after class.” Others reported that “they met with groups of students in the library for a more relaxed and personal setting” and “were asked if they could tutor outside of class.” “[Students] had access to contact me outside of the class to ask questions or advice. It felt great to know that I was there to help them both inside and outside of the classroom.” Being asked “for an email address” was mentioned by several mentors to allow for continued contact after the class was completed.

These outside of classroom experiences show a desire to connect with their students beyond the confines of the classroom and prescribed experience. Mentors supported students whenever and wherever opportunities presented themselves. This level of support was unique in that these mentors had similar students and time commitments as the other peer leaders. Despite these constraints, mentor peer leaders expressed a desire for outside of class interactions and anticipation of student needs. These outside interactions were exclusively mentioned by mentors.
Every group of peer leader stated that they had students who would not come to class prepared and were not engaged. A key difference between mentors and other perceived role groups was that mentors viewed their students as having the potential to improve but lacking the skills and motivation to grow. Mentors reported they would “help students set goals” or “learn better study habits.” This mentality of bettering students showed responsibility for their students’ learning that extended beyond the typical PLTL experience. There was no indication that the mentors did not embrace their role as facilitators. The difference between guide/facilitator and mentor can be summed up with this peer leader’s statement:

I wanted to say that I saw myself as a facilitator, by answering questions with a question my students slowly got to the right answer but from my experience I think being a peer leader is much more than that. I see myself more of as a mentor to the students. I made sure to set myself in the same plane as them.

**Implications for Peer Leader Training**

‘Teacher, then guide and facilitator, then mentor’ forms a progression in peer leader-student relationships. Teaching is helpful; however, this role does not embrace the engagement envisioned for PLTL and is merely an extension of a lecture mode of instruction. Facilitators and guides are the ideal role envisioned by the developers of PLTL (Becvar et al., 2008). Mentorship has been observed in classrooms implementing peer leading; however, this role is not formally addressed in the PLTL literature (c.f., Wilson & Varma-Nelson, 2016) nor emphasized in PLTL training programs. Since peer leading is a multi-discipline teaching pedagogy the mentoring of young STEM majors could help bridge the continued gap of representation in disciplines where females and URM students are still underrepresented such as technology, engineering, applied physics, and math (Wilson & Varma-Nelson, 2016).
Guides and facilitators are focused on promoting meaningful learning beyond teaching students the content or demonstrating a failsafe method for solving a problem. The Socratic method of questioning is the ideal PLTL pedagogical strategy. Peer leader training programs are intended to provide guidance on learning pedagogies involving groups and opportunities to practice promoting student engagement. Peer leaders are to identify the needs of their students and provide targeted, individualized assistance. Peer leaders are to support collaborative and autonomous (i.e., apart from a formal instructor) learning. Based on these ideal activities of peer leaders, a guide or facilitator role best describes the archetype peer leader (c.f., Becvar et al., 2008). These roles though embrace a perspective that the peer leaders and students are different. The theoretical foundation of PLTL, however, acknowledges the importance of the similarities between peer leaders and students that begs and creates an opportunity for a more mentorship-style relationship.

Mentors stated more often than the other roles about building deeper, more personal relationships with their students. From a peer mentor perspective, these relationships provide a means for broader conversations about the course (e.g., how to best study for examinations), future course enrollments (e.g., Dr. Bartlett provides similar peer leading experiences in their recitation sessions), and shared experiences (e.g., when I took this course, I had a similar struggle learning this particular material). Having a peer with similar shared experiences participating in these conversations could prove beneficial as Seymour and Hewitt (1997) implied that the decision undergraduates make to leave science, math, and engineering was always based on a culmination of discussions that the students have with others. This mentoring process does not need to overshadow the PLTL program. But encouraging peer leaders to be open about their experiences when interacting with students may allow for this process to happen more organically. While we do not have quantitative data to specifically support this claim, the research literature suggests that a peer leader who espouses a more mentor-style role is more effective at promoting meaningful learning and retention in STEM (e.g., Becvar et al., 2008; Colvin
& Ashman 2010; Damkaci et al., 2017; Martin & Dowson, 2009). Moore & Amey (1988) point out that mentoring can also be covered in a multitude of different roles, i.e. guide, teacher, patron, depending on the needs of the protégé.

**Limitations and Future Directions**

We wonder how solidified these roles are, influences beyond preparedness or participation that led to particular perceived roles, and if these roles are fluid and responsive to student needs each session. We also wonder if students perceived these roles espoused by their peer leaders and how these roles may have influenced the students’ experiences and learning. Classroom observations of peer leader-student interactions and observations of peer leader training sessions were not conducted as part of this study; this limits our ability to corroborate the situations described by the peer leaders and to evaluate the influence that training sessions may have had on the roles peer leaders perceived they were to espouse, including how the peer leaders were referred to by the instructor in these training sessions.

Not every peer leader mentor mentioned what interactions specifically caused them to have this identity of mentor to their students. However, as this journal entry was the final entry of the semester and was asking for their overall view of themselves throughout the course, it can be assumed that there were experiences that happened to cause them to think of themselves as such. It is possible that this holistic view of an entire semester does not account for individual moments of mentoring that could have been done by those peer leaders in other role categories and the peer leader simply did not view that as their main role during the semester.

Despite these limitations and new questions asked, there is an opportunity for more mentorship-oriented training to be included in peer leader training programs that capitalize and formalize mentoring that is informally occurring in the context of PLTL. Non-PLTL peer mentoring programs have shown promise in chemistry contexts (e.g., Damkaci et al., 2017). Coupling PLTL with
Peer mentoring can provide a more holistic approach to promoting achievement and retention. Mentoring could be in several forms but based on our analysis it should be used as both a psychosocial and developmental format.

**Conclusion**

Our results demonstrate that peer leaders perceive their roles in the classroom based on experiences had during their interactions with students through implementing the anticipated PLTL pedagogy of facilitation and use of guiding questioning and a desire to build relationships with the student both inside and outside the classroom setting. Peer leader trainers should be cognizant of how peer leaders enact their roles, especially for identifying when peer leaders settle on a more teacher-focused role which can be caused by a lack of student preparedness. Mentoring should be encouraged and integrated into peer leader training programs; PLTL and peer mentoring share many commonalities from which a synergistic combination could lead to greater achievement and retention. This integration can be simple and does not have to change the principles of PLTL but discussion of how to be empathetic to their students, and how to look for opportunities to mentor students could be discussed in weekly trainings. Understanding how these perceived roles impact student experiences and learning would provide needed evidence for the importance of promoting a more mentorship-style of peer-led team learning.

**Acknowledgements**

We would like to thank the 52 peer leaders who provided the data from which this study was conducted. In addition, the context for the study, i.e. the peer-led team learning program, was supported by the National Science Foundation (DUE-1432085); any opinions, findings, and conclusions or recommendations in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.
References


Chapter 5

Development and Evaluation of Scales for Measuring Self-Efficacy and Teaching Beliefs of Students Facilitating Peer-Supported Pedagogies

Note to Reader

This chapter is a published manuscript in the *Journal of the Scholarship of Teaching and Learning*:


This work was published with a co-author. Jeffrey R. Raker is the principal investigator for this project.

Abstract

Two scales measuring teaching self-efficacy and beliefs were developed from previous instruments for use with near-peer facilitators assisting with peer-supported pedagogies. Construct and face validity, measurement reliability, and factor structure were determined using a population of near-peer facilitators working in a peer-led team learning chemistry classroom at a large research-intensive postsecondary institution in the Southeast United States. Results suggest that the scales produce valid and reliable data. Teaching self-efficacy and beliefs were found to increase between pre and post administrations with small to medium effect sizes. The scales can provide a means to evaluate peer-supported pedagogies and as discussion points for faculty members training near-peer facilitators.
Introduction

Peer leaders, learning assistants, and the like are becoming integral components of active learning pedagogies being incorporated into science, technology, engineering, and mathematics (STEM) courses. Such pedagogies are rooted in constructivist views of learning, wherein near peers (i.e., students who have completed the course) are utilized in lecture periods (e.g., Robert, Lewis, Oueini, & Mapugay, 2016), recitation and discussion sections (e.g., Tien, Roth, & Kampmeier, 2002), or supplemental instruction sessions (e.g., Chan & Bauer, 2015) as a means to better bridge the zone of proximal development (i.e., the gap between where the students are and the most realistic jump in understanding achievable at that moment, Vygotsky, 1978). The efficacy of peer-supported pedagogies shows considerable promise for addressing success in gateway courses and retention in STEM degree programs (Tien, Roth, & Kampmeier, 2002; Michael, 2006; Salomone & Kling, 2017; Freeman et al., 2014; Perera, Wei, & Mlsna, 2019). While much is known about the learning and learning experiences of students completing courses that utilize peer-supported pedagogies, less is known about the experiences of the peer instructors. Particularly given the importance of teaching self-efficacy and teaching beliefs of course instructors and graduate teaching assistants on learning, there is a gap in the literature on understanding the self-efficacy and beliefs of the near peers facilitating such pedagogies. We thus report the development and evaluation of an instrument to measure the teaching self-efficacy and beliefs of near-peer facilitators. This new instrument can be used to evaluate the impact of a peer-supported learning experience, evaluate the impact of self-efficacy and teaching beliefs on achievement, and inform associated near-peer professional development programs.
Peer-Led Team Learning and Learning Assistant Pedagogies

Two key near-peer pedagogies are utilized in postsecondary STEM courses: peer-led team learning (PLTL) and learning assistants (LAs). These, and other similar active-learning pedagogies involving near-peer instruction, rely on experienced undergraduates working with current students on coursework and other learning experiences. These pedagogies have at their core the goal of decreasing the student-instructor ratio in large classes, wherein the near-peer facilitators are considered instructors in the course.

Near-peer facilitators are selected based on success in the course that they will be working within; although not a requirement, many peer instructors have experienced peer-supported pedagogies in the course for which they are assisting. Near-peers guide students through individual and small group activities ranging from single classroom-response system questions (e.g., clicker questions), to back-of-the-chapter textbook problems, to multi-question guided learning worksheets (e.g., Tien, Roth, & Kampmeier, 2002; Michael, 2006; Arendale, 2010; Salomone & Kling, 2017; Freeman et al., 2014; Perera, Wei, & Mlsna, 2019). While peer instructors often answer questions, the goal of a near-peer is to ‘facilitate’ learning; therefore, they often respond to student questions with a different question to help guide students to their own answer (Wilson & Varma-Nelson, 2016; Tenney & Houck, 2003; Drane, Smith, Light, Pinto, & Stewart, 2005; Tien, Roth, & Kampmeier, 2002; Arendale, 2010; Salomone & Kling, 2017; Freeman et al., 2014; Perera, Wei, & Mlsna, 2019). Learning facilitation, in this way, requires confidence in facilitating learning as well as a belief that collaborative learning is an effective pedagogy. Initial, and typically weekly training programs are designed to promote the confidence development and reinforce learning beliefs of the near-peers (e.g. Varma-Nelson & Cracolice, 2001), a training experience often modelled after near-peer supported instructional sessions with the instructor of the course acting in the role of the near-peer, and the near-peers acting in the role of the students.
**Peer-Led Team Learning (PLTL)**

PLTL has been shown to promote achievement in many STEM disciplines (e.g., Wilson & Varma-Nelson, 2016; Tenney & Houck, 2003; Drane, Smith, Light, Pinto, & Stewart, 2005; Tien, Roth, & Kampmeier, 2002), with notable increases in achievement for underrepresented STEM students (Stewart, Amar, & Bruce, 2007). The pedagogy was first implemented in postsecondary chemistry courses to provide students with the support to solve problems, develop a better understanding of course material, and make connections between course concepts; PLTL has since been reported in an array of STEM disciplines (e.g. chemistry: Mitchell, Ippolito, & Lewis, 2012; Chan & Bauer, 2015; Frey, Fink, Cahill, McDaniel, & Solomon, 2018; math: Hooker, 2011; engineering Loui & Robbins 2012; Horwitz, et al., 2009) and non-STEM disciplines (e.g. nursing: White, Rowland, & Pesis-Katz, 2012). Peer leaders (i.e., near-peer facilitators in PLTL) facilitate groups of three to four students in completing the designated learning activity (Gosser et al., 1996). This facilitation is based on social constructivism (Vygostsky, 1978), a learning theory that knowledge is created in mind of the learner (Bodner, 1984) and learning is boosted by social interactions (Driver, Asoko, Leach, Mortimer, & Scott, 1994).

Studies on PLTL have been categorized into five themes by Wilson & Varma-Nelson (2016): student success measures; student perceptions; reasoning and critical thinking skills; research on peer leaders; and variants of the traditional PLTL model. Student success has been measured in numerous aspects within STEM programs (e.g. grades: Chan & Bauer, 2015; Frey, Fink, Cahill, McDaniel, & Solomon, 2018; Hooker, 2011; Loui & Robbins, 2012; Horwitz et al., 2009; White, Rowland, & Pesis-Katz, 2012; standardized final exams: Mitchell, Ippolito, & Lewis, 2012; Chan & Bauer, 2015; and retention: Mitchell, Ippolito, & Lewis, 2012; Hooker, 2011; Horwitz et al., 2009; Drane, Smith, Light, Pinto, & Swarat, 2005). Student perceptions of their learning, as measured by Finn and Campisi (2015), have been shown to increase positively. Critical thinking skills, as measured by the California Critical Thinking Skills Test, have been shown to increase (Quitadamo, Brahler, & Crouch, 2009. A key critique is that
“time on task” or “time engaged with tasks” is greater for PLTL learning experiences, and thus, student-level metrics are expected to increase (Chan & Bauer, 2015).

The last two themes from Wilson and Varma-Nelson (2016) consider how the PLTL experience effects peer leaders and the how varying the PLTL experience can affect the process. When interviewed after participating in a PLTL course as near-peers, 92% of former peer leaders positively rated their peer leading experience due to an increase for appreciation of small-group learning, different learning styles, efforts made by teachers, as well as an increased confidence in presenting and working as a team (Gafney & Varma-Nelson, 2007). Peer leaders who adopt a facilitator approach to their interactions with students were more likely to acknowledge, build upon, and elaborate ideas as opposed to a more instructional based approach lend to students working individually when not listening to the peer leader, be answer-focused, and unequally participate (Brown, Sawyer, Frey, Luesse, & Gealy, 2010). Integrating active collaboration was found to be a potentially crucial element as it was discovered that organic chemistry students that participated in cyber PLTL (a synchronous online version of PLTL) had significantly less success drawing the correct predicted product of a chemical reaction (Wilson & Varma-Nelson, 2018). Facilitating collaborations is necessary to catalyze social constructivist learning experiences.

**Learning Assistants (LAs)**

Learning assistants (LAs) are similar to peer leaders of PLTL in that their primary goal is to facilitate learning and reduce the student-to-instructor ratio (Otero, Pollock, McCray, & Finkelstein, 2006; Otero, Pollock, & Finkelstein, 2010). A key component of LAs is the focus on pedagogical content knowledge (Shulman, 1986) as the underlying theoretical framework with an emphasis on content, pedagogy, and practice (Otero, Pollock, & Finkelstein, 2010). Weekly planning sessions with the course instructor are used to review the content. Occasionally, LAs enroll in a teaching and learning course to gain a better understanding of the learning processes and how to best facilitate learning (Otero, Pollock,
McCray, & Finkelstein, 2006; Otero, Pollock, & Finkelstein, 2010). Learning assistants are incorporated into instruction in two ways: First, facilitating small group work activities similar to the PLTL pedagogical model. Second, assisting with clicker questions, similar to the Mazur’s (1997) peer instruction pedagogical model, wherein the LAs are additional instructors during the peer instruction experience. Otero et al. (2006) have reported that fostering interest in the teaching profession (particularly, K12 instruction) is a secondary goal of learning assistant programs. Unlike PLTL with its origin in chemistry, the origin of LA programs is not attributed to one discipline; LA programs are now found in many disciplines: biology (Sellami, Shaked, Laski, Eagan, & Sanders, 2017); physics (Otero, Pollock, McCray, & Finkelstein, 2006); and chemistry (Jardine & Friedman, 2017).

**Teaching and Learning Beliefs**

An instructor’s beliefs about teaching are related to the instructional practices implemented in their courses (Lotter, Harwood, & Bonner, 2007; Simmons et al., 1999; Gibbons, Villafañe, Stains, Murphy, & Raker, 2018). The implication is that instructors implement pedagogies deemed to be beneficial to learning. When instructors perceive that the best way of learning is through transmission of knowledge, more lecture-based pedagogies are reported by such instructors and observed in their classrooms. When instructors perceive that learning is best through construction of knowledge, additional small, group work-based pedagogies are reported and observed. These beliefs about learning have origins in how the instructor believes they learn best (Simmons et al., 1999). Thus, an instructor’s experience as a student has a powerful influence on their views of teaching (Smith, 2005; Trigwell, Prosser, & Waterhouse, 1999; Kember & Kwan, 2000).

Unlike instructors who predominately have experienced more lecture-based pedagogies in their postsecondary and graduate education, near-peer facilitators have the unique experience of typically having participated as a student in active learning pedagogies prior to their participation in peer-supported instructional pedagogies. Self-selection to be a near-peer facilitator could be, in part, the
result of a belief in the effectiveness of the pedagogy. We expect that near-peer facilitators will have some foundational belief in collaborative approaches to learning. Streitwieser and Light (2010) found, through qualitative interviews, that peer instructors implementing PLTL had strong student-centered beliefs about teaching; they also found that peer leaders had positive or no changes in teaching beliefs as a result of their peer leading experience. Johnson, Robbins, and Loui (2015) found through reflection journals that leaders learned to appreciate intellectual diversity among students and that the leaders expressed an increased interest in teaching. French and Russell (2002) found that as graduate teaching assistants gained experience implementing inquiry-based laboratory experiments, they conceptualized their role in learning more as a guide than a conveyer of information. This ‘guide’ role is a typical characterization of how peer instructors should perceive their role in instruction (Gosser et al., 1996; Hockings, DeAngelis, & Frey, 2008; Kampmeier, Varma-Nelson, & Wedegaertner, 2000). (Clark & Raker, in press) found that peer leaders report different interactions with students based on how they perceived their role; for example, peer leaders viewing themselves as “mentors” reported engaging with students beyond the scope of assignment including providing broad study skill advice and sharing their experience in the course, in comparison to peers leaders viewing themselves as “teachers” reported more transmission of knowledge interactions including feeling the need to “give students the answers” when the learning activity was challenging.

Teaching beliefs, though, do not, by default, translate into instructional practice (Addy & Blanchard, 2010; Volkmann & Zgagacz, 2004). Confidence in one’s ability to enact instructional practices (i.e., teaching self-efficacy) is also associated with pedagogical choices.

**Teaching Self-Efficacy**

Self-efficacy refers to an individual’s belief about their capability to achieve a specific task (Bandura, 1986). Lack of confidence in a task can lead to avoidance of the task. Typically within STEM disciplines, we think about the confidence a student has in solving problems and answering questions,
and how that confidence relates to their achievement on an assessment (e.g., Pajares, 1996; Ferrell & Barbera, 2015; Britner & Pajares, 2006; Cheung, 2015; Zeldin, Britner, & Pajaras, 2008; Villafañe, Xu, & Raker, 2016). Teaching self-efficacy is confidence in one’s ability to teach in specific ways, and how that confidence relates to how and what occurs in the classroom (c.f., Gibbons, Villafañe, Stains, Murphy, & Raker, 2018).

While there is an absence of literature on the teaching self-efficacy of near-peer facilitators, investigations into the teaching self-efficacy of graduate teaching assistants provide insight into what to expect with near-peer facilitators. Bond-Robinson and Bernard Rodriques (2006) found that low confidence may preclude effective teaching by graduate teaching assistants. Reeves et al. (2018) analyzed pretest/posttest data with first time biology and chemistry laboratory graduate teaching assistants using the Anxiety and Confidence in Teaching scale; they found statistically significant gains in graduate teaching assistants’ teaching self-efficacy and pedagogical knowledge, with significant reductions in teaching anxiety.

Research has shown that teaching self-efficacy impacts teacher behaviors, and by association student outcomes. A teacher’s self-efficacy beliefs positively impact student learning and the actual success or failure of a teacher’s behavior (Henson, 2002). Teachers with high teaching self-efficacy tend to perform better, have a greater desire to continue teaching, and their students have higher achievement metrics (Ashton & Webb, 1986; Tschannen-Moran, Hoy, & Hoy 1998). Teaching self-efficacy typically develops early in a teacher’s career and becomes relatively stable over time (Morris & Usher, 2011; Tschannen-Moran, Hoy, & Hoy 1998). Morris and Usher (2011) found that early successful instructional experiences, which were are a combination of mastery experiences (i.e., having a command of the course content) and positive feedback from students in the course and fellow instructors, are important for developing high teaching self-efficacy of twelve teaching award winning professors, and that their teaching self-efficacy solidified within the first few years as a faculty member.
These studies suggest that experiences in peer-supported instruction, and as a near-peer facilitator, may lead to more active learning experiences being incorporated into postsecondary educational settings as these postsecondary students begin to seek and commence careers in academia.

**Research Purpose and Questions**

The purpose of our study is to develop and evaluate an instrument to measure the teaching and learning beliefs and teaching self-efficacy of peer instructors. Our work is guided by two key questions:

1. Do the Teaching Belief Scale and Self-Efficacy Scale produce valid and reliable data?
2. What change in teaching and learning beliefs and teaching self-efficacy occur as a result of participation as a peer instructor?

**Methods**

**Research Setting**

Data were collected at a large research-intensive university in the Southeastern United States between Fall 2017 and Spring 2019. PLTL is implemented in two variations at the research setting: First, PLTL is incorporated into weekly 50-minute recitation sessions for the first semester general chemistry course. Peer leaders facilitate up to six small groups of three to four students per recitation session, completing worksheets created by the course instructors; on average, 1,500 students are enrolled in the course each term, with peer leaders facilitating up to two recitation sessions per week.

Second, PLTL is incorporated into half of the second semester general chemistry course lecture periods. In this variation, students in the course watch instructional videos prior to each peer learning lecture periods (i.e., flipped-class approach). Peer leaders then facilitate up to four small groups of three to four students within the context of a large-lecture hall completing worksheets created by the course instructors; up to 24 peer leaders are simultaneously assisting in the lecture period. The course instructor is also present in the classroom assisting with small group facilitation and interjecting classroom response questions (i.e., clickers) to formatively assess learning throughout the lecture
period. On average, 500 students are enrolled in second semester PLTL-based general chemistry courses each term.

Peer leaders enrolled in a three-credit training course for both the first and second semester general chemistry courses. The training course was instructed by chemistry faculty members with experience implementing and evaluating PLTL. Within the training course, peer leaders discussed how to facilitate learning, potential problems and opportunities encountered in implementing PLTL, and experienced the small group learning activity from the perspective of a student.

**Scale Development**

Our teaching self-efficacy and beliefs scales evolved from the *Teaching Assistant Professional Development* (TAPD) survey reported by Wheeler, Maeng, Chiu, and Bell (2017); the TAPD survey originated from the *College Teaching Self-Efficacy Scale* (Navarro, 2005) and the *STEM Graduate Teaching Assistant-Teaching Self-Efficacy Scale* (DeChenne, Enochs, & Needham, 2012). The TAPD is composed of two scales: beliefs (8 items) and self-efficacy (13 items). The TAPD instrument was intended for use with graduate teaching assistants, and thus revisions and additions were necessary to focus the instrument for use with near-peer facilitators.

We first removed mentions of specific course structures (e.g., “Laboratory courses should be used primarily to reinforce a science idea that the students have already learned in lecture”) to broaden the utility of the tool across multiple chemistry courses that may or may not have instructional laboratory components. TAPD items addressing two ideas were split into two items. Referents to “chemistry” were added to multiple items to focus respondents on the particular course. Eight beliefs items were added to the instrument to address constructivist underpinnings of peer-supported pedagogies. Nineteen self-efficacy items were added to the instrument to address the numerous tasks expected of near-peer facilitators as reported in literature on PLTL and LA programs. A five-point confidence scale from “not at all confident” to “extremely confident” was adopted in congruence with
the TAPD survey. A total of 14 beliefs items and 32 self-efficacy items were evaluated in our study. The resulting items were reviewed by four chemistry education researchers and two general chemistry instructors to establish face validity.

Participants

Peer leaders completed the instrument during the first week of term before they led a peer leading session (pre), and again at the end of the term after their last peer leading session (post). Data were collected via Qualtrics over four academic terms (Fall 2017, Spring 2018, Fall 2018, and Spring 2019). Peer leaders received credit for completing the instrument amounting to 5% of their overall grade in the training course. The instrument was administered to 227 peer leaders, with 211 peer leaders (93%) completing all items at both administrations. With 9 peer leaders completing just one administration. Therefore 431 individual response instances were collected. Peer leaders can only serve for one term at the research setting; therefore, participants had no prior experience serving in the role prior to the study.

Data Analysis

Data were pooled and then split into an exploratory analysis set (n = 217 responses) and a confirmatory analysis set (n = 214 responses). These samples are sufficient for conducting the proposed analyses (Costello and Osborne, 2005). Principle components exploratory factor analyses (EFA) with Varimax rotation, Kaiser Criterion, and Scree tests were conducted using SPSS 24.0 on each scale (i.e., beliefs and self-efficacy) to determine the internal structure. Confirmatory factor analysis (CFA) was conducted using Mplus 7.31 on each scale to verify internal structure. Comparative fit indices (CFI) greater than 0.90 and root mean square error of approximation (RMSEA) values less than 0.08 determine good fit (Browne & Cudeck, 1993). RMSEA values can be unreliable, however, with models that have a small degrees of freedom (Kenny, Kaniskan, & McCoach, 2015). Internal consistency was measured with using JASP (https://jasp-stats.org) to measure McDonald’s omega values; an omega
coefficient greater than 0.60 indicates acceptable consistency (Cortina, 1993). Because of the randomization process it is possible that some individuals had both their pre and post responses recorded in either the EFA or CFA.

Results

Teaching Beliefs Scale - Development

Exploratory factor analysis of the Teaching Beliefs Scale originally suggested between one- and five-factor solutions with support from Kaiser Criterion, eigenvalues greater than one. Inspection of the Scree plot indicated either a two-factor or three-factor solutions. Loadings from the three-factor solution resulted in a non-result, and so the two-factor solution was examined with the removal of one item (see Table 5.1) due to the item (14) cross loading across both factors. Upon closer inspection of the two-factor items revealed that one factor was a collection of items that would be considered non-supportive of social constructivism. To verify this, the five items (1,2,5,8,12) were reversed coded; the resultant EFA was again two-factor with the non-supportive items grouping together. Because of the redundancy of two factors differing only in positive or negative valence, the five non-supportive items were removed. This left one factor with eight items in the teaching beliefs scale (see Table 5.2). This parsimonious set of items resulted in a one-factor solution with support from the Kaiser Criterion and Scree plot. All factor loadings were significant at p<.05.

Table 5.1

Teaching Beliefs Scale - First iteration and reasons for item removal

<table>
<thead>
<tr>
<th>Item</th>
<th>Reason Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry instruction should cover many topics superficially to maintain interest from the largest variety possible of students</td>
<td>NS</td>
</tr>
<tr>
<td>Students learn chemistry best when grouped with students of similar abilities</td>
<td>NS</td>
</tr>
<tr>
<td>Inadequacies in students’ chemistry knowledge and skills can be overcome through effective teaching</td>
<td></td>
</tr>
<tr>
<td>Students should be provided with the reason for why the content they are learning is important</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.1 (Continued)

| Personal studying is the best way to learn chemistry | NS |
| Chemistry instruction should be aimed at helping students make connections between their science courses | |
| Students learn chemistry best when grouped with students of differing abilities | |
| Learning from peers is not helpful in chemistry because they do not have the same level of understanding as a professor | NS |
| Small group work should be used to learn chemistry | |
| Chemistry courses should provide opportunities for students to share their thinking and reasoning | |
| Small group work should be used to reinforce concepts already learned in lecture | |
| Chemistry instruction that makes connections to other science courses can lead to confusion | NS |
| Chemistry instruction should focus on ideas at an in-depth level, even if that means covering fewer topics | CL |
| Small group work should be used to learn new concepts | |

Note. Items are listed in the order in which they were presented to the respondent. “CL” denotes cross-loading. “NS” denotes a non-supportive item.

Table 5.2

Teaching Belief Scale - Final iteration

<table>
<thead>
<tr>
<th>Level of agreement with the following statements</th>
<th>Factor loadings$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inadequacies in students’ chemistry knowledge and skills can be overcome through effective teaching (TB1)</td>
<td>0.282</td>
</tr>
<tr>
<td>Students should be provided with the reason for why the content they are learning is important (TB2)</td>
<td>0.401</td>
</tr>
<tr>
<td>Chemistry instruction should be aimed at helping students make connections between their science courses (TB3)</td>
<td>0.516</td>
</tr>
<tr>
<td>Students learn chemistry best when grouped with students of differing abilities (TB4)</td>
<td>0.314</td>
</tr>
<tr>
<td>Small group work should be used to learn chemistry (TB5)</td>
<td>0.500</td>
</tr>
<tr>
<td>Chemistry courses should provide opportunities for students to share their thinking and reasoning (TB6)</td>
<td>0.752</td>
</tr>
<tr>
<td>Small group work should be used to reinforce concepts already learned in lecture (TB7)</td>
<td>0.541</td>
</tr>
<tr>
<td>Chemistry instruction should focus on ideas at an in-depth level, even if that means covering fewer topics (TB8)</td>
<td>0.329</td>
</tr>
</tbody>
</table>

| Eigenvalue | 2.512 |
| Percent (%) of total variance explained | 31.41 |
| Factor mean$^2$ | 4.06 |
| McDonald’s omega | 0.61 |

$^1$Principal axis factor analysis

$^2$Items coded on a 5-point scale of 1 = Strongly disagree to 5 = Strongly disagree
Inspection of the items within the factor suggest the emergence of a single factor with 8 items using a WLSMV parameter estimator which is required for ordinal and categorical data. Item statistics and Spearman rho correlations for the Teaching Beliefs Scale are reported in Table 5.3 and Table 5.4.

CFA on the confirmatory data set supports the one-factor solution: $\chi^2(20) = 52.553, p = .0001, \text{CFI} = 0.908, \text{RMSEA} = 0.087$ (see Figure 5.1).

**Table 5.3**

*Teaching Beliefs Scale - Item statistics and Spearman rho correlations*

<table>
<thead>
<tr>
<th>TB1</th>
<th>TB2</th>
<th>TB3</th>
<th>TB4</th>
<th>TB5</th>
<th>TB6</th>
<th>TB7</th>
<th>TB8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>431</td>
<td>431</td>
<td>431</td>
<td>431</td>
<td>431</td>
<td>431</td>
<td>431</td>
</tr>
<tr>
<td>min.</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>max.</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>median</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>mean</td>
<td>4.26</td>
<td>4.23</td>
<td>3.95</td>
<td>3.68</td>
<td>3.98</td>
<td>4.26</td>
<td>4.42</td>
</tr>
<tr>
<td>std. dev.</td>
<td>0.67</td>
<td>0.81</td>
<td>0.91</td>
<td>1.07</td>
<td>0.74</td>
<td>0.65</td>
<td>0.61</td>
</tr>
<tr>
<td>skewness</td>
<td>-0.91</td>
<td>-1.22</td>
<td>-0.86</td>
<td>-0.60</td>
<td>-0.65</td>
<td>-0.92</td>
<td>-0.78</td>
</tr>
<tr>
<td>kurtosis</td>
<td>1.72</td>
<td>1.88</td>
<td>0.32</td>
<td>-0.55</td>
<td>1.00</td>
<td>2.67</td>
<td>0.91</td>
</tr>
</tbody>
</table>

TB1 1.00 .30** .16** .04 .16** .26** .22** .08
TB2 1.00 .30** .10* .17** .28** .12* .14**
TB3 1.00 .15** .24** .39** .20** .22**
TB4 1.00 .22** .20** .22** .10*
TB5 1.00 .43** .42** .14**
TB6 1.00 .45** .14**
TB7 1.00 .16**
TB8 1.00
TB9

Note. * $p < .05$; ** $p < .01$.

**Table 5.4.**

*Self-Efficacy Scale - Item statistics and Spearman rho correlations*

<table>
<thead>
<tr>
<th>SE1</th>
<th>SE2</th>
<th>SE3</th>
<th>SE4</th>
<th>SE5</th>
<th>SE6</th>
<th>SE7</th>
<th>SE8</th>
<th>SE9</th>
<th>SE1</th>
<th>SE1</th>
<th>SE1</th>
<th>SE1</th>
<th>SE1</th>
<th>SE1</th>
<th>SE1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$n$</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>43</td>
<td>435</td>
<td>435</td>
<td>435</td>
<td>435</td>
<td>435</td>
<td>435</td>
<td>435</td>
</tr>
<tr>
<td>min.</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>max.</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>median</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

124
Table 5.4 (Continued)

<table>
<thead>
<tr>
<th></th>
<th>SE1</th>
<th>SE2</th>
<th>SE3</th>
<th>SE4</th>
<th>SE5</th>
<th>SE6</th>
<th>SE7</th>
<th>SE8</th>
<th>SE9</th>
<th>SE10</th>
<th>SE11</th>
<th>SE12</th>
<th>SE13</th>
<th>SE14</th>
<th>SE15</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>4.4</td>
<td>4.2</td>
<td>4.5</td>
<td>4.3</td>
<td>4.5</td>
<td>4.2</td>
<td>4.1</td>
<td>4.0</td>
<td>3.9</td>
<td>4.4</td>
<td>4.4</td>
<td>4.5</td>
<td>4.3</td>
<td>4.3</td>
<td>4.3</td>
</tr>
<tr>
<td>std. dev.</td>
<td>0.6</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>0.8</td>
<td>0.7</td>
<td>0.9</td>
<td>0.7</td>
<td>0.6</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>skewness</td>
<td>0.9</td>
<td>0.6</td>
<td>1.0</td>
<td>0.7</td>
<td>1.1</td>
<td>0.6</td>
<td>0.6</td>
<td>0.8</td>
<td>0.3</td>
<td>1.2</td>
<td>0.6</td>
<td>1.2</td>
<td>0.9</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>kurtosis</td>
<td>1.1</td>
<td>0.0</td>
<td>0.4</td>
<td>0.3</td>
<td>1.1</td>
<td>0.0</td>
<td>0.4</td>
<td>0.3</td>
<td>0.5</td>
<td>1.3</td>
<td>0.0</td>
<td>1.7</td>
<td>0.9</td>
<td>0.5</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Note. All correlations are significant, p < .01.
McDonald’s omega is 0.61 for the factor indicating acceptable reliability for a low stakes test measuring change in beliefs about teaching. While McDonald’s omega is sensitive to the number of items; 8 items seem reasonable to give appropriate results (Cortina, 1993; Murphy & Davidshofer, 2005). Items TB4 and TB8 have lower than normally accepted values (< .400); however, we believe that these items are integral to the overall theoretical construct. We agree with Bandalos and Finney (2019) that while variable elimination is an important part of the process for creating a model, researchers should be less cavalier with the elimination of variables because doing so changes the construct. Bandalos and Finney (2019) suggest retaining any questionable variable until further research can be done to verify if the transgressing variable repeats upon replication of the study. These psychometric measures suggest that the scales produce valid and reliable data.

**Self-Efficacy Scale - Development**

Exploratory factor analysis of the initial 32-item self-efficacy scale (see Table 5.5) using the exploratory data set suggested a one-factor solution based on the Scree plot; Kaiser criterion suggested up to four factors; however, three of those factors had eigen values near one. As such a one-factor solution is a probable solution.
Table 5.5

*Self-Efficacy Scale - First iteration and reasons for item removal*

<table>
<thead>
<tr>
<th>Item</th>
<th>Reason Removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a positive atmosphere for learning in small groups</td>
<td></td>
</tr>
<tr>
<td>Encourage students to ask their fellow students questions</td>
<td></td>
</tr>
<tr>
<td>Show students that I have a personal investment in their learning</td>
<td></td>
</tr>
<tr>
<td>Think of my students as active learners as opposed to information receivers</td>
<td></td>
</tr>
<tr>
<td>Learn all of my students’ names</td>
<td>DNL</td>
</tr>
<tr>
<td>Provide encouragement to students who are doing well</td>
<td></td>
</tr>
<tr>
<td>Let students take initiative for their own learning</td>
<td></td>
</tr>
<tr>
<td>Evaluate students’ conceptual understanding of chemistry</td>
<td>HC</td>
</tr>
<tr>
<td>Discuss in-depth chemistry content with students</td>
<td></td>
</tr>
<tr>
<td>Correct students’ incorrect ideas in a positive way</td>
<td>HC</td>
</tr>
<tr>
<td>Actively engage my students in the small group learning activities</td>
<td>HC</td>
</tr>
<tr>
<td>Show my students respect through my actions</td>
<td>NN</td>
</tr>
<tr>
<td>Promote student participation in small group work</td>
<td>HC</td>
</tr>
<tr>
<td>Address student questions that you do not immediately know the answer to</td>
<td>HC</td>
</tr>
<tr>
<td>Deal with disputes between students</td>
<td></td>
</tr>
<tr>
<td>Gain students’ trust</td>
<td>HC</td>
</tr>
<tr>
<td>Be a representative of the course instructor</td>
<td></td>
</tr>
<tr>
<td>Encourage students to interact with each other</td>
<td>HC</td>
</tr>
<tr>
<td>Motivate students to study outside of required class time</td>
<td></td>
</tr>
<tr>
<td>Promote a positive attitude toward learning chemistry</td>
<td></td>
</tr>
<tr>
<td>Share personal insights on learning the course material</td>
<td></td>
</tr>
<tr>
<td>Spend personal time preparing for students’ needs</td>
<td></td>
</tr>
<tr>
<td>Assist students in clarifying their attitudes and ideas about chemistry</td>
<td>HC</td>
</tr>
<tr>
<td>Relate to students from different backgrounds and life experiences</td>
<td></td>
</tr>
<tr>
<td>Help students develop a willingness to share ideas</td>
<td>HC</td>
</tr>
<tr>
<td>Show students that I have a personal investment in them and their success</td>
<td>HC</td>
</tr>
<tr>
<td>Provide opportunities for students to receive immediate feedback on their learning</td>
<td>HC</td>
</tr>
<tr>
<td>Encourage students to ask me questions in class</td>
<td>HC</td>
</tr>
<tr>
<td>Strengthen students’ interpersonal relationship skills</td>
<td>HC</td>
</tr>
<tr>
<td>Provide support to students who are having difficulty learning</td>
<td>HC</td>
</tr>
<tr>
<td>Help students set reasonable goals for learning the course material</td>
<td>HC</td>
</tr>
<tr>
<td>Improve the critical thinking skills of my students</td>
<td>HC</td>
</tr>
</tbody>
</table>

*Note.* Items are listed in the order in which they were presented to the respondent. “DNL” denotes does not load onto factor. “NN” denotes non-normal. “HC” denotes highly correlated.

To obtain a more parsimonious self-efficacy scale, we engaged in multifaceted item reduction. First, examination of EFA factor loadings showed one item that did not load onto a factor. Second, one item (“Show my students respect through my actions”) was extremely non-normal (kurtosis = 6.19).
Lastly, Spearman correlations were evaluated between scale items to determine redundancy; values greater than 0.4 were examined with 15 items being removed due to correlating to a large number of other items. An EFA was run on the resulting 15 items of the exploratory set; per EFA criterion, a one-factor solution was best. Factor loadings are between 0.50 and 0.68 for all items of the self-efficacy scale (see Table 5.6).

**Table 5.6**

**Self-Efficacy Scale - Final iteration**

<table>
<thead>
<tr>
<th>How confident am I in my ability to...</th>
<th>Factor Loading$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Create a positive atmosphere for learning in small groups (SE1)</td>
<td>0.618</td>
</tr>
<tr>
<td>Encourage students to ask their fellow students questions (SE2)</td>
<td>0.625</td>
</tr>
<tr>
<td>Show students that I have a personal investment in their learning (SE3)</td>
<td>0.641</td>
</tr>
<tr>
<td>Think of my students as active learners as opposed to information receivers (SE4)</td>
<td>0.601</td>
</tr>
<tr>
<td>Provide encouragement to students who are doing well (SE5)</td>
<td>0.597</td>
</tr>
<tr>
<td>Let students take initiative for their own learning (SE6)</td>
<td>0.578</td>
</tr>
<tr>
<td>Discuss in-depth chemistry content with students (SE7)</td>
<td>0.556</td>
</tr>
<tr>
<td>Address student questions that you do not immediately know the answer to (SE8)</td>
<td>0.636</td>
</tr>
<tr>
<td>Deal with disputes between students (SE9)</td>
<td>0.560</td>
</tr>
<tr>
<td>Be a representative of the course instructor (SE10)</td>
<td>0.644</td>
</tr>
<tr>
<td>Motivate students to study outside of required class time (SE11)</td>
<td>0.608</td>
</tr>
<tr>
<td>Promote a positive attitude toward learning chemistry (SE12)</td>
<td>0.643</td>
</tr>
<tr>
<td>Share personal insights on learning the course material (SE13)</td>
<td>0.579</td>
</tr>
<tr>
<td>Spend personal time preparing for students’ needs (SE14)</td>
<td>0.479</td>
</tr>
<tr>
<td>Relate to students from different backgrounds and life experiences (SE15)</td>
<td>0.607</td>
</tr>
<tr>
<td><strong>Eigenvalue</strong></td>
<td>6.009</td>
</tr>
<tr>
<td><strong>Percent (%) of total variance explained</strong></td>
<td>40.06</td>
</tr>
<tr>
<td><strong>Factor Mean$^2$</strong></td>
<td>4.34</td>
</tr>
<tr>
<td><strong>McDonald’s omega</strong></td>
<td>0.91</td>
</tr>
</tbody>
</table>

$^1$Principal axis factor analysis

$^2$Items coded on a 5-point scale of 1 = not at all confident to 5 = very confident

CFA on the confirmatory analysis data set supports the one-factor solution: $\chi^2(90) = 202.61, p < .0001$, CFI = 0.966, RMSEA = 0.076 (see Figure 2). WLSMV was used as the parameter estimator.

McDonald’s omega is 0.91 for the confirmatory analysis data set. These psychometric measures suggest that the instrument produces valid and reliable data.
Impact of Participation in Peer Leading

Spearman’s rho correlations between the Teaching Beliefs Scale and the Self-Efficacy Scale by pre and post measures are reported in Table 5.7; only peer leaders who had completed all pre and post items are included in this analysis (n = 211). These correlations suggest that the constructs are related; however, the constructs are independent (rho < .75) and are not autocorrelated between pre and post measures.

Table 5.7

Correlations between study measures at pre and post administrations

<table>
<thead>
<tr>
<th></th>
<th>Self-Efficacy (Pre)</th>
<th>Constructivist Teaching Beliefs (Pre)</th>
<th>Self-Efficacy (Post)</th>
<th>Constructivist Teaching Beliefs (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SE(Pre)</td>
<td>1.00</td>
<td>.27</td>
<td>.45</td>
<td>.23</td>
</tr>
<tr>
<td>TB(Pre)</td>
<td></td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE(Post)</td>
<td></td>
<td></td>
<td>1.00</td>
<td>.47</td>
</tr>
<tr>
<td>TB(Post)</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note. p < .01. N=211

Differences between pre and post measures are determined using Wilcoxon signed rank tests (see Table 5.8). The Wilcoxon signed test is a comparison of pre and posttests, similar to a t-test but has more flexibility in that it allows for non-parametric data to be examined. Significant pre/post differences...
were observed for both factors with increasing Self-Efficacy and increasing constructivist Teaching Beliefs; these differences have small to medium effect sizes: \( r = z / \sqrt{(n_{\text{pre}} + n_{\text{post}})} \) (Cohen, 1988; Pallant, 2007).

**Table 5.8**

*Wilcoxon signed rank tests between pre and post administrations*

<table>
<thead>
<tr>
<th>Factor</th>
<th>median (Pre)</th>
<th>mean (Pre)</th>
<th>std. dev. (Pre)</th>
<th>median (Post)</th>
<th>mean (Post)</th>
<th>std. dev. (Post)</th>
<th>Z</th>
<th>p</th>
<th>r (size)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Efficacy</td>
<td>4.13</td>
<td>4.13</td>
<td>0.50</td>
<td>4.53</td>
<td>4.49</td>
<td>0.41</td>
<td>-9.03</td>
<td>&lt; .001</td>
<td>0.440 (medium)</td>
</tr>
<tr>
<td>Teaching Beliefs</td>
<td>4.00</td>
<td>3.98</td>
<td>0.39</td>
<td>4.13</td>
<td>4.13</td>
<td>0.44</td>
<td>-4.43</td>
<td>&lt; .001</td>
<td>0.216 (small)</td>
</tr>
</tbody>
</table>

**Discussion and Implications**

Two scales, a Teaching Beliefs Scale and a Self-Efficacy Scale, were developed to measure the impact of peer-supported instruction experiences on near-facilitators in postsecondary chemistry courses. Exploratory factor analyses were conducted on half of the data set, followed by item-reduction procedures in order to obtain parsimonious measures. Confirmatory factor analyses were conducted on the remaining half of the data set. Suitable psychometric evidence for the validity and reliability of the data were obtained to justify initial use of the instrument.

The developed instrument serves two purposes: First, as used in this study, administration of the instrument in a pre/post manner can provide evaluative data on the combined impact of any professional development experiences (i.e., weekly peer leader training in our study) and experiences implementing peer-supported instruction (i.e., enacting PLTL experiences). Use of the scales at multiple settings should include additional reliability and validity investigations. Second, results of the two scales can inform trainers of peer leaders and learning assistants as to initial confidence levels and teaching beliefs prior to professional development experiences; thus, we suggest the scales be used as a formative assessment tool to measure the current state of the near-peer facilitators. Administration of
the instrument followed by a whole group discussion could serve to further prepare the near peers for their learning facilitator roles. Because of the convenience and prevalence of online surveys the complete instrument for each scale is presented within the paper complete with the 5-point Likert scale.

We hope that use of these scales becomes implemented across near-peer programs across the globe.

Our tool was developed for chemistry programs which limits its transferability as near-peer programs exist in a variety of disciplines (Wilson & Varma-Nelson, 2016). Previous instruments such as the Achievement Emotions Questionnaire (AEQ; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011) have been taken from a general context and converted into chemistry specific (AEQ-OCHEM; Raker, Gibbons, & Cruz-Ramírez de Arellano, 2019) and we hope that future researchers will implement the reverse in creating discipline specific variations so the impact can be universal.

Looking at the long-term effects of peer-leading on individuals Gafney and Varma-Nelson (2007) found similar results as the individuals that they surveyed finding that 32% (n=38) of those surveyed described a new appreciation for differences among people, particularly in how they learn or understand new material. In the same study 28% (n=33) reported increased confidence, comfort, or patience in working with people, particularly in teaching-learning situations which relates well with our findings of increase self-efficacy (Gafney & Varma-Nelson, 2007). In today’s society installing students with activities that give them opportunities for growth are vital. In a study comprising 875 students from 10 institutions done by Cress, Astin, Zimmerman-Oster, and Burkhardt, showed that when students are involved in leadership activities, they “showed growth in civic responsibility, leadership skills, multicultural awareness, understanding of leadership theories and personal and societal values.” While this study did not look at near-peer facilitating specifically we believe that the principles learned during near-peer facilitating are supporting these leadership values and will continue to play a role in the betterment of near-peer facilitators.
Positive impacts of the peer instruction experience on self-efficacy mirror those found with graduate teaching assistants (Burton, Bamberry, & Harris-Boundy, 2005; Prieto & Almaier, 1994; Prieto, Yamokoski, & Meyers, 2007; Tollerud, 1990). The effect size of our pre/post teaching beliefs differences are much lower, potentially confirming that teaching beliefs are malleable, but may be resistant to change; such a conclusion is support by studies on the teaching beliefs of postsecondary instructors (Morris & Usher, 2009; DeChenne, Enochs, & Needham, 2012; Simmons et al., 1999). Given the importance of learning experiences both as a student and as a facilitator of learning on future choices to enact instructional practices (Sunal et al., 2001), the data from our developed scales show promise for a long-term, broader impact on instruction should our participants choose to pursue a career in education.

Teaching beliefs and self-efficacy, by proxy through how these constructs are related to the use of more effective pedagogies, are associated with increase course performance (Ashton & Webb, 1986; Tschannen-Moran, Hoy, & Hoy, 1998). While such an investigation is beyond the scope of the study we report herein, our scales could be used in further work to identify the association between peer instructor espoused beliefs and self-efficacy, and the performance of students for whom the peer instructor assists in facilitating learning. Analogous studies have been conducted considering the beliefs and efficacy of graduate teaching assistants (e.g. Prieto & Almaier, 1994; Prieto, Yamokoski, & Meyers, 2007; DeChenne, Enochs, & Needham, 2012; Wheeler, Maeng, Chiu, & Bell, 2017).

Conclusions

Two scales were created to help measure the teaching self-efficacy and beliefs of near-peer facilitators assisting with peer-supported pedagogies. These instruments were taken from previous work done that addressed teaching assistants and general teaching, however it is believed that the unique context of near-peer facilitators deemed that more specific scales be developed. Construct and face validity, measurement reliability, and factor structure were determined and show that the scales
produce reliable data, although we recommend that additional research be conducted in order to extend
the scope and validity of our work. Teaching self-efficacy and beliefs were found to increase among
near-peer facilitators between pre and post administrations with small to medium effect sizes. These
newly developed scales can provide a means for faculty training near-peer facilitators to efficiently
evaluate their students and programs and can help serve as discussion points for improving their
programs.

Limitations

Three key limitations should be noted for our study: First, the development of instruments that
produce valid and reliable data necessitate a sufficient number of respondents in order to conduct
thorough psychometric evaluations. Four iterations of data collection were necessary at our research
setting in order to collect a sufficient number of respondents even with the large number of peer
leaders facilitating general chemistry courses each term; we expect for smaller institutions and smaller
courses that even more data collection iterations would be necessary. Despite our sufficient sample size,
we acknowledge that more data is needed to further confirm our results and establish stronger
evidence for the reliability and validity of data generated by our instrument.

Second, while our instrument is designed for near-peer facilitators, our instrument development
and psychometric evaluations were conducted with a specific type of near-peer facilitators: peer leaders
in a peer-led team learning pedagogical environment. Given the parallel roles of peer leaders and
learning assistants, we do not anticipate that the instrument will function differently; however, we
recommend thorough psychometric evaluations when using the tool in any new setting, and strongly
recommend when using the tool with learning assistants.

Third, Likert-scale self-report is one form of data from which to gather teaching beliefs and self-
efficacy data. Interview data, reflection essays, and even observation data can provide additional
insights into the experiences of near-peer facilitators; such methods have shown to be a value for
studies of teachers and graduate teaching assistants. These additional data courses would provide a more holistic understanding, including triangulation of assertions. While data collected from all methods synthesized in a single study may be impractical (and a burden on participants to provide such copious data), studies parallel to those of teachers and graduate teaching assistants would further illuminate the dimensionality of teaching beliefs and self-efficacy of near-peer facilitators.

Acknowledgements

We would like to thank and acknowledge the peer leaders who participated in this study. Additionally, we would like to thank the peer leader trainers/course instructors who allowed us to collect data in their courses.

References


Clark, A., & Raker, J. (conditionally accepted) Development of the PLTL scale measuring peer leader self-efficacy, and teaching beliefs. *Journal of the Scholarship of Teaching and Learning*


Chapter 6

Conclusions and Implications

This chapter is a summary of the research reported in this dissertation (see Chapter 3, Chapter 4, and Chapter 5), and overarching conclusions and implications from those studies. Implications are presented as specific examples of how the work described in this dissertation could be implemented by chemistry instructors (Implications 1-3) and used to inform future work by chemistry education researchers (see Implications 4-6).

Summary of Studies

The overarching goal of this dissertation research was to consider how researchers and practitioners can implement more social constructivist teaching practices into postsecondary chemistry courses. These teaching practices include promoting deep and collaborative approaches for learning in organic chemistry courses and through implementation of effective implementation of peer-led team learning (PLTL) pedagogies, namely focusing on training for peer leaders, in both organic chemistry and general chemistry courses.

The first study (see Chapter 3) was focused on the approaches students used when learning organic chemistry. The goal of this project was to identify reasons why students, who were predicted to be successful, tended to struggle in organic chemistry. Sixteen students were interviewed in the first semester of a yearlong organic chemistry course to understand how students were engaging in deep, collaborative learning while studying (i.e., engagement in learning strategies congruent with social constructivism). Two frameworks (Marton & Saljo 1976; Tang, 1993) were used to code the data, creating four characterizations that could be used show approaches students used into relative categories: surface-individual, surface-collaborative, deep-individual, and deep-collaborative. Results of this study
showed that there was a pattern with deep versus surface learning and performance in the course, but there was less of a relationship with collaborative versus individual approaches and performance. It should be noted that all Chapter 3 study participants had previously enrolled in a PLTL-based general chemistry course that emphasized the importance and effectiveness of collaborative learning; therefore, it is informative that 14 of the 16 participants did not report participating in collaborative learning when studying in the target course. Encouraging effective deep learning through collaboration with peers either through interventions or demonstrations could begin to open pathways towards success in the course and by extension success in degree programs and professional schools (e.g., medical school) that require success organic chemistry.

In the second study (see Chapter 4), social learning was studied from the perspective of how peer leaders view their roles in an organic chemistry course that uses the PLTL pedagogy. PLTL pedagogy has collaborative, small group learning as its focus. Peer leaders have their primary goal to be facilitators of learning within those small groups, and thus reduce the student-to-instructor ratio in the classroom context (Otero, Pollock, McCray, & Finkelstein, 2006; Otero, Pollock, & Finkelstein, 2010). To collect data for this study, 52 peer leaders supporting PLTL pedagogies in an organic chemistry course responded to a journal entry prompt asking them to select a role they most filled in the context of peer leading and to provide an example of how they enacted that role. Despite ‘facilitator’ being the intended role for peer leaders, participants reported that ‘mentor’ was the role they most associated with their experience as a peer leader. A key idea that emerged is that peer leaders are approaching their interactions with their students in a myriad of ways, whether that be by instructing students, or by encouraging students to participate in collaborative learning with their peers, or by providing psychosocial support and being role model for their students. Few PLTL studies have mentioned mentorship (e.g. Damkaci, Braun, & Gublo, 2017) as an intended peer leader role; to date, no systematic studies on mentorship in PLTL have been reported in the research literature (c.f., Wilson & Varma-Nelson, 2016).
In the final study in this dissertation (see Chapter 5), social learning was considered from the perspective of peer leader’s self-reported efficacy for enacting and beliefs about social learning. Evidence from studies of postsecondary instructors show that higher levels of self-efficacy and more active learning-based teaching beliefs are associated with positive student outcomes and higher levels of student achievement (Ashton & Webb, 1986; Tschannen-Moran, Hoy, & Hoy, 1998). With ever increasing implementation of PLTL and similar programs (c.f., Raker, Dood, Srinivasan, & Murphy, 2021) having scales that can measure teaching self-efficacy and teaching beliefs of peer leaders, or near-peers (e.g., learning assistants) is critical to demonstrating continued and renewed success.

The scales developed and reported in Chapter 5 originated from previously reported instruments for graduate teaching assistants (Wheeler, Maeng, Chiu, & Bell, 2017; Navarro, 2005), and showed that the teaching self-efficacy and teaching beliefs of peer leaders were high on the scale before the course began. There were positive, small to medium effect size changes for both scales indicating that change did happen over the course of the semester. The developed scales can be used by peer leader trainers to quickly evaluate what peer leaders believe about the effectiveness of their teaching and their use of social constructivism in their teaching. This can help identify problems or concerns of the peer leaders in a quick and efficient manner. Additionally, the two scales can be useful tools for educators to show how their programs are helping peer leaders improve in both their self-efficacy and their beliefs about teaching; for example, the scales could be used in a pre-post experimental design with a training experience or the peer leading experience as the intervention.

**Implications for Instructors**

Results of the work presented in this dissertation support three overarching implications for instructors (see Implication 1, Implication 2, and Implication 3). These implications center on modelling and promoting deep, collaborative learning (Implication 1), as well as purposeful training and evaluation of peer leaders within the context of implemented PLTL pedagogies (Implication 2 and Implication 3).
Implication 1: Instructors Need to Demonstrate What Deep and Collaborative Learning is for Students.

An assumption that organic chemistry instructors often make is that students know how to approach studying effectively for the course. Studies, including the one presented in Chapter 3, suggest that students do not always have such a firm understanding of how to study (e.g., Anderson & Bodner, 2008; Grove & Bretz, 2010). Thus, there is a need for instructors to demonstrate and facilitate the development of effective learning frameworks for students, in particular, deep and collaborative learning approaches, i.e. approaches with theoretical and empirical foundations for their benefits for learning (Credé & Kuncel, 2008). As shown in Chapter 3, a majority of participants did not use deep approaches, and even fewer participants utilized collaborative learning when studying for the course. The participants almost universally (15 of 16 total participants) stated that they used more surface and individual approaches for other classes and have found success (i.e., high course grades) with that approach. Organic chemistry was often the first subject in which the students reported not finding success with a more individual and memorization-based approach. This need to adjust study approaches would help confirm ideas about how study habits and approaches to learn are related to students leaving STEM (Weston, Seymour, Koch, & Drake, 2019) or deciding to change career paths (Lovecchio & Dundes, 2002). Such adjustments, to a more deep and collaborative study approach, may also open a pathway for more students to find success in chemistry courses, specifically organic chemistry.

What is meant by deep and collaborative study approaches? First, it is not sitting around a table with people simply checking answers to homework problems with each other or with the solutions manual. Deep and collaborative learning is having a conversation among peers or near-peers. It is asking questions and teaching each other. Questions should require more than a yes or no response. There should be discussions on the how and why of the topic, in this case, organic chemistry. Organic chemistry is inherently about making connections and drawing conclusions based on available data: the strength of a base, the bulkiness of a reagent, the inductive or resonance effect’s role in a reagents
ability to undergo a reaction, etc. The ability to make meaningful connections can help make organic chemistry an enlightening experience for students; for example, how hydrogen bonding explains secondary structure in proteins. Organic chemistry students who approach the course from this perspective are more likely to be able to make those connections and adapt to being able to problem solve base on prior knowledge (e.g. Anderson and Bodner 2008; Grove & Bretz 2012). Trigwell, Prosser, and Ginns (2005) argued that students with a deep approach to learning are inherently interested and attempt to understand what they study, whereas students adopting a surface approach primarily focus on rote learning and mainly study to pass the test.

Describing these interactions to students is insufficient; it is important for instructors to model and demonstrate deep-collaborative learning. This demonstration should be done near the beginning of the semester to maximize the benefits to students. This could be done during class time where the instructor and a teaching assistant (or student for smaller classes) do a homework problem. Topics such as Lewis acid–base theory would be a prime candidate for this as it is a concept that organic chemistry students struggle with and is generally taught near the beginning of organic chemistry courses. The ‘study group’ would then answer a question like which side of this acid–base reaction is favored with starting materials of a typical organic reaction (e.g. ethoxy and acetic acid). The instructor could then repeatedly ask the teaching assistant why? Or to explain their reasoning even with simple questions. After doing several questions the instructor can pause and ask students to do this with a partner near them, focusing on asking them why they choose an answer and to use deeper reasoning then just memorized facts. As part of this demonstration the students could design their own acid–base equilibrium question and then other students could be prompted to ascertain the whys of the question. Giving feedback on the objective of questions could allow for a deeper level of understanding in order to properly give such feedback.
Implication 2: Training of Peer Leaders for Peer-Led Team Learning (PLTL) Should Include an Active Mentoring Component.

Chapter 4 described how peer leaders, supporting PLTL in a postsecondary organic chemistry course, perceived their role. In particular, many peer leaders described engaging in mentoring activities despite mentoring not being an explicit role intended for peer leaders. Mentoring has many dimensions. From the perspective of Kram (1983), mentoring should, at minimum, focus on role modeling (e.g., “how to do chemistry”) and psychosocial support (e.g., building up self-confidence of the students). Such a mentoring relationship with students extends beyond the typical activities that a peer leader is trained to enact; however, mentoring has been suggested in the literature as a possible informal role that peer leaders play (Gosser et al., 2001). There is an opportunity to formalize mentoring in peer leader training, furthering the net positive impact of PLTL on learning.

Approaching peer leading from a holistic, mentoring framework has the potential to benefit students within and beyond the target course, creating opportunities for long-term development and engagement within the institutional community; for example multiple studies have shown that mentoring programs improve study skills, motivation, academic and personal adjustment (Jacobi, 1991; Redmond, 1990; Tinto, 1987; Upcraft and Gardner, 1989). In addition, mentoring relationships could forge opportunities for engaging in undergraduate research and further work in science (Atkinson & Bolt, 2010). Many higher education institutions have mentoring programs for first-year students and students for particular demographic groups (e.g., for people of color; Colvin & Ashman, 2010). In their review of mentoring in higher education over the last ten years, Lunsford, Crisp, Dolan, and Wuetherick, (2017) found that mentoring is a means of directly or indirectly improving academic outcomes, such as grade point average and persistence. Such mentoring programs provide guidance to students on how to navigate the ‘ins and outs’ of college (Colvin & Ashman, 2010). Extending mentoring programs to target
student populations that are defined by taking a particular academic course has the potential to further extend student success.

Having programs that incorporate both a mentoring aspect (i.e. adjusting to college life) and also a learning aspect (i.e. course specific) has been shown to give positive. One such chemistry program in Puerto Rico, as studied by Báez-Galib, Colón-Cruz, Resto, and Rubin (2005), purposefully incorporated a mentoring aspect into their PLTL-like program. The near-peer leaders had two prescribed roles: mentors and tutors. As mentors, the near peers promoted active participation in the learning teams by primarily providing effective communication, listening, and sharing. The near peers were also tasked with imparting a positive attitude intended to instill self-confidence in the students. This led to a support network between the students, the near-peers (i.e., tutor-mentors), and the professors. The tutoring aspect was different than a traditional PLTL course in that students came to the near peers with questions not assigned to be worked on in a small group (i.e., PLTL). The near peers, however, were instructed to guide students through the learning process and not give answers away but let the students discover the knowledge for themselves.

Mentoring training sessions can be simple additions to the program, in particular in the context of follow-up with peer leaders about their peer leading experiences (Jackling & McDowall, 2008). For example, asking peer leaders if they had any students who seemed to be disengaged during the session. Giving examples of how they could ask students if there is something outside of class that is bothering them and giving the peer leaders information of campus services that can address issues such as mental health concerns. Or asking other peer leaders to share how they have interacted with students when faced with the same situation; this strategy has the potential to create dialogue between peer leaders, empowering the peer leaders to create a mentoring network among themselves. Another purposeful activity to promote mentoring: during registration week for the upcoming semester, ask peer leaders to
take a moment with their students to expound on what classes the peer leader found enjoyable and why they choose the classes they took.

Nick et al. (2012) articulated six essential categories that are needed for establishing a productive, formal mentoring program. First, achieve appropriately matched dyads through the use of pairing scenarios or seeking input from both protégé and mentor. This could be done through a simple survey to see which students would be similar to which peer leader. Demographics with student minorities in chemistry such as race, gender, sexuality, etc. could be matched with similar peer leaders. Career goals (e.g. premed, grad school) could also be considered. Second, establish clear mentorship purpose and goals by setting a clear time commitment, and establishing the reciprocity of the relationship and the benefits gained by both those giving and receiving the mentoring. Explain to both the students and peer leaders that the peer leaders are there to help mentor the students. This mentoring can be through advice giving or through psychosocial support. Third, solidify the dyad relationship by establishing mutual respect and trust through regular feedback and communication. Have peer leaders be honest with their students in expectations but also with struggles. For example, a peer leader could let them know that they, personally, did not do well on the first exam when they took the course what they did to overcome that struggle. Fourth, advocate for and guide the protégé through psychosocial support and advising. Let the peer leaders know what they should and should not say in regard to experiences with coursework and professors. For example, saying a certain instructor is the worst and gives really terrible exams could be rephrased as the instructor’s exams do not match up with their lectures and it makes that class difficult. Meaningful, specific, but still honest feedback without being mean-spirited. The peer leaders represent the department, but they also can give more personalized experiences. Fifth, integrate the protégé into the academic culture by assisting with teaching networking skills and culture expectations. The peer leaders can help students learn how to approach faculty or utilize campus resources that students may not be familiar with. For example, many
of the peer leaders are upperclassmen so they might be participating in research groups or doing
volunteer hours, the peer leaders can talk about how they got into such programs and how they
reached out to certain professors and programs. Finally, mobilize institutional resources: Obtain
departmental support and include mentoring as part of the peer leader job description.

**Implication 3: Training of Peer Leaders for Peer-Led Team Learning (PLTL) Should Include Evaluation of Peer Leaders Facilitating Learning.**

Much of the higher education teacher training is done with a ‘sink or swim’ approach. In other
words, professors, instructors, graduate teaching assistants, undergraduate teaching assistants, learning
assistants, etc. receive little training on teaching (c.f., Gardner & Jones, 2011; Addy & Blanchard, 2010).
While it is reported that peer leaders need to be trained (Wilson & Varma-Nelson, 2016), there is little
documentation in the research literature that training extends beyond training sessions or involves
observation and evaluation of peer leaders once they are engaged in enacting the PLTL pedagogy.

Training of peer leaders before the academic term and weekly/ongoing throughout the term
should be supplemented with observations of the peer leaders enacting the pedagogy, discussions
about those observations with individual and groups of peer leaders, and revision of training programs
to further promote good learning facilitation practices. Thus, a feedback loop would be created of
training, observation, discussion, and revision of training. Observations could be short (and thus,
potentially frequent), approximately five minutes observing a peer leader’s interactions with a limited
number of small groups. These observations would be looking for demeanor (is the peer leading
standing in an aggressive/closed stance for example) or is the peer leader engaging everyone in the
group. This does not need to be a scored setting, but general observations of better personal
interactions and habits could be very beneficial to peer leaders and indirectly students. Similar brief
observations have shown benefit with instructors (Atkinson & Bolt, 2010). PLTL instructors might find
that they gain a better understanding of learning by their students and the overall success of PLTL through such observations.

The self-efficacy and beliefs about teaching and learning scales reported in Chapter 5 have the potential to inform peer leader teaching observations, conversations, and feedback regarding those observations. The various aspects of confidence in enacting constructivist pedagogies as measured by the self-efficacy scale and the various beliefs regarding constructivist pedagogies as measured by the beliefs scale could be interpreted and discussed in relation to corresponding observations. Additionally, the scales have the potential to provide a quantitative measure of the development of peer leaders. Such development could also be interpreted and discussed with individual peer leaders at the end of their experience to help the peer leaders. For example, an instructor may find a lower score on the teaching beliefs scale (indicating a belief that individual learning is better). This would mostly be caused by students who succeed well in the course on their own. This belief that students learn better on their own because that is what they did when they took the course. The peer leader instructor could then have a discussion with the peer leaders that while for some students individual learning may work the goal of the program is to have meaningful collaborative learning opportunities.

Implications for researchers

The results of the work presented in this dissertation support three overarching implications for researchers (see Implication 4, Implication 5, and Implication 6). These future work implications address evaluating interventions and programs proposed as a result of this dissertation research (Implication 4 and Implication 5), and association studies between peer leader self-efficacy and beliefs about learning, and student outcomes (Implication 6).

Implication 4: Evaluate the impact of study approach interventions on student outcomes

Results presented in Chapter 3 suggest that despite prior work and known difficulties in postsecondary organic chemistry course, there remains a need for explicit and targeted interventions
that facilitate students developing quality study habits. In Implication 1, ideas were articulated for how such interventions could be conducted. The focus of this Implication is on implementing such interventions and testing the efficacy of those interventions. While a parallel experimental-control study seems probable for such a study, to withhold an intervention that assumes to help students is unethical. Thus, a series experimental-control study that relies on historical data (i.e., assessment data and course metrics from prior offerings of the course compared with offerings of the course that implement the intervention/new program) is the most practical. Such a design has been utilized in many chemical education research studies (c.f., ANOVA, Lyle & Robinson, 2003; comparison of final examination scores, Grove & Bretz, 2008). Students in the current iteration of the course would be encouraged or obliged to study in groups and efforts would be made to encourage students to ask each other questions meant to invoke deep learning. Then the scores of the final examination would be compared to a previous year ideally with similar class sizes, allowing instructors to compare differences between the two groups, a Wilcoxon signed-rank test. When the assessment data are available, outcomes beyond content should be considered; for example, self-efficacy (e.g., Villafañe, Xu, & Raker, 2016), motivation (e.g., Ferrell, Phillips, & Barbera, 2016), or achievement emotions (e.g., Raker, Gibbons, & Cruz-Ramírez de Arellano, 2019). While content-based outcomes are important, students leave STEM for a variety of reasons (Weston, Seymour, Koch, & Drake, 2019) many of which would be considered beyond content or performance related. Studying these outcomes can lead researchers to understand the other influences on student choices.

**Implication 5: Evaluate the Impact of Incorporating Mentoring into Peer-Led Team Learning Programs on Student Outcomes.**

The proposed research in Implication 5 involves evaluating the impact of the proposed activities in Implication 2. As argued for in Chapter 4, mentoring is a spontaneous activity occurring in the context of PLTL programs. Peer leaders are role modeling and providing psychosocial support to their students
without prompting from course instructors. In Implication 2, ideas are articulated for how a mentoring component could be formally incorporated into PLTL programs. In this Implication, evaluation of such a program is outlined. Mentoring programs designed for target populations (e.g., people of color or first-generation students) have effectiveness metrics of retention and graduation (c.f., Campbell & Campbell, 1997); such metrics parallel PLTL effectiveness metrics (e.g., retention, Drane, Smith, Light, Pinto, & Swarat, 2005; Hockings, DeAngelis, & Frey, 2008; continued participation in STEM courses, Drane, Micari, & Light, 2014). Thus, a series experimental-control study, similar to what was proposed in Implication 4, would be most appropriate wherein success metrics are compared between PLTL implementation with and without a mentoring component. Again, the research design of a series experimental-control study that relies on historical data and utilizes a t-test statistic for comparisons between the two groups, such as a Wilcoxon signed-rank test.

**Implication 6: Evaluate the Association Between Peer Leader Self-Efficacy and Beliefs About Teaching & Learning with Student Outcomes.**

In Chapter 5, development of two scales was reported that measure teaching self-efficacy and teaching beliefs. These scales are tools that allow for quick assessment of peer leaders’ perspectives that can inform training programs both formatively and summatively. When considering graduate students and faculty instructors, these two constructs have been shown to be associated with increased student outcomes (e.g., Ashton & Webb, 1986; Tschannen-Moran, Hoy, & Hoy 1998); there is, thus, an opportunity for parallel studies with peer leaders to be conducted. While such studies would be correlation/association based, results could be the starting point for more in-depth studies that include observations and interviews to fully explore any causal relationships between peer leaders’ affect and student outcomes; for example, Park and Hannum (2001) have conducted such studies of teachers’ affect and student outcomes and found that quality of teacher has a correlation to higher math achievement scores.
As a final note, the two scales reported in Chapter 5 have suitable psychometric properties for initial reporting in the research literature; however, further use of the scales should include continued investigation of internal structure and reliability of data from the scales. The data thus far collected with these scales were not collected via the proposed shorten versions. As such, the reliability of data should be tested through administration of the shortened scales. Data were also only collected from first time peer leaders; thus, data need to be collected from a broader spectrum of peer leaders. Lastly, studies of longitudinal measurement invariance are needed when the measures are used in a pre/post fashion; this is necessary to ensure that comparisons across various groups of participants are both meaningful and valid. These proposed psychometric evaluations are the next step in ensuring the scales are functioning as intended and thus are providing data that are valid and reliable for conducting the proposed correlation studies.

Summary

The theme of this dissertation work is the importance of social constructivism to learning. It is recommended that social constructivism permeate how instructors approach helping students to understand how better to study (c.f., Chapter 3) and how classroom instruction is best facilitated, herein, PLTL is strongly advocated (c.f., Chapter 4 and Chapter 5). Organic chemistry instructors should demonstrate effective ways to implement deep and collaborative learning approaches (Implication 1). PLTL instructors need to take a more active role in observing and evaluating peer leaders’ learning facilitation skills (Implication 2). Additionally, PLTL instructors have an opportunity to easily measure peer leaders’ self-efficacy and learning beliefs (Implication 3). These instructor-focused implications mirror a set of research-focused implications that call for evaluating the impact of study skill interventions (Implication 4), inclusion of a formal mentoring component in PLTL pedagogies (Implication 5) and measuring the association between peer leaders’ affect and student outcomes.
(Implication 6). The work reported in this dissertation, and associated implications, reinforce the importance of active, engaging pedagogies in the context of postsecondary chemistry courses.

References


Christian, K., & Talanquer, V. (2012) Content-related interactions in self-initiated study
groups. *International Journal of Science Education, 34*(14), 2231-2255.


Appendix A: Interview Protocols

ID: Pro00036606
Title: Learning Strategies in Postsecondary Organic Chemistry Courses

INTERVIEW PROTOCOL - First Interview

Introduction:
Thank you for agreeing to talk with me about your experiences taking organic chemistry. The purpose of this interview is to recognize patterns and behaviors that organic chemistry students utilize in learning organic chemistry. Our goal is to develop a descriptive understanding of what your experience is taking organic chemistry.

Before we get started, do you have any questions for me?

Interview:
For the first set of questions, I would like to better understand about your experience at USF. The questions are open-ended; please feel free to engage with me about what I’m asking, what I mean, and if anything about the questions need clarification. I will occasionally be asking follow-up questions; before I do that, I want to hear your thoughts first. Please don’t worry about sounding repetitive or off topic.

1. Please tell me about your experience as a student at USF.
   a. What is your major?
      Why did you choose your major?
   b. What classes are you taking this term?
      i. What classes have you taken previously?
   c. What chemistry courses have you taken at USF? at other higher education places?
2. Please share with me when and how you have studied in general for your classes this semester.
   a. Who, if anyone, did you study with?
      i. How did you meet these people?
      ii. Do you study with these same people every time?
   b. Where have you studied?
3. Thinking about this term specifically, what outside of class activities (e.g., job, student organizations, family, etc.) have you regularly engaged in?
   a. How many hours a week do you work? Sports? Family events? Other time commitments?
   b. Do you have any leadership roles in those student organizations?

Now I would like to ask a few questions about your experience taking organic chemistry this term.
1. When and how you have studied for your organic chemistry course this term?
   a. Who, if anyone, did you study with?
      i. How did you meet these people?
      ii. Do you study with these same people every study session? Is it consistent?
   b. Where have you studied? How often?

2. Now that you’ve taken the first exam,
   a. What has gone well with studying for that exam?
   b. What has not gone well with studying for that exam?
   c. What do you hope to do differently for the rest of the term?

For the next part of the interview, I’m going to give you two problems on material that was tested on the first examination. I would like for you to solve the problems. While you are working through the problems, I would like for you to describe, out loud, what you are thinking and what you are doing.

Problem 1
(A). Use arrows to show electron flow for this reaction.
(B). Label the acid, base, conjugate acid, and conjugate base for this reaction.
(C). Describe in full detail what you think is happening on the molecular level for this reaction. Be sure to discuss the role of each reactant.
(D). Using a molecular level explanation, please explain why this reaction occurs. Be sure to discuss why reactants form the products shown.

\[
\begin{align*}
\text{(A)} & : \quad \cdot O^- + \cdot H\cdot O\cdot H & \quad \rightarrow & & \cdot H\cdot O\cdot H + \cdot O^- \\
\text{(B)} & : \quad \text{acid} & \quad \text{base} & \quad \text{conjugate acid} & \quad \text{conjugate base} \\
\text{(C)} & : \quad \text{molecular reaction} \\
\text{(D)} & : \quad \text{molecular explanation}
\end{align*}
\]

Problem 2
(A). Use arrows to show electron flow for this reaction.
(B). Label the Lewis acid and the Lewis base for this reaction.
(C). Describe in full detail what you think is happening on the molecular level for this reaction. Be sure to discuss the role of each reactant.
(D). Using a molecular level explanation, please explain why this reaction occurs. Be sure to discuss why reactants form the products shown.

\[
\begin{align*}
\text{(A)} & : \quad \cdot O^+ + \cdot H\cdot O\cdot H & \quad \rightarrow & & \cdot H\cdot O\cdot H^+ + \cdot O^- \\
\text{(B)} & : \quad \text{Lewis acid} & \quad \text{Lewis base} \\
\text{(C)} & : \quad \text{molecular reaction} \\
\text{(D)} & : \quad \text{molecular explanation}
\end{align*}
\]

To be answered after each of the above problems:
1. Now that you have completed the problem, please describe for me how you solved the problem. Did you have a strategy for solving the problem?
2. In studying for your last exam, did you prepare for problems like this one? If so, how did you go about studying for problems like this one?
3. What was hard/easy about the problem?
4. How is this problem similar/dissimilar to problems you had to solve on your last exam?

You’ve now been in class for several weeks and you’ve taken the first exam. If you could travel back in time, what advice would you give someone else right before the semester began?

Before we end the survey, is there anything else about your experience in organic chemistry so far this term that you would like to share?

Thank you! I will be contacting you later in the term to set up a second interview.
INTERVIEW PROTOCOL - Second Interview

**Introduction:**
Thank you for agreeing to talk with me again about your experiences taking organic chemistry. The purpose of this interview is to recognize patterns and behaviors that organic chemistry students utilize in learning organic chemistry. Our goal is to develop a descriptive understanding of what your experience is taking organic chemistry.

Before we get started, do you have any questions for me?

**Interview:**
For the first set of questions, I would again like to understand better about your experience this semester at USF. The questions are open-ended; please feel free to engage with me about what I’m asking, what I mean, and if anything about the questions need clarification. I will occasionally be asking follow-up questions; before I do that, I want to hear your thoughts first. Please don’t worry about sounding repetitive or off topic.

1. Please share with me when and how you have studied in general for your classes this semester.
   a. Who, if anyone, did you study with?
      i. How did you meet these people?
      ii. Do you study with these same people every time?
   b. Where have you studied?

2. Thinking about this term specifically, what outside of class activities (e.g., job, student organizations, family, etc.) have you regularly engaged in?
   a. How many hours a week do you work? Sports? Family events? Other time commitments?
   b. Do you have any leadership roles in those student organizations?

Now I would like to ask a few questions about your experience taking organic chemistry this term.

1. When and how have you studied for your organic chemistry course this term?
   a. Who, if anyone, did you study with?
      i. How did you meet these people?
      ii. Do you study with these same people for all your courses?
   b. Where have you studied?

2. Now that you’ve taken several exams,
   a. What has gone well with studying for those exams?
   b. What has not gone well with studying for those exams?
   c. What exam did you feel was the most challenging? What made it the most challenging?
   d. Did you study differently for the exams?
For the next part of the interview, I’m going to give you two problems on material that was tested this semester. I would like for you to solve the problems. While you are working through the problems, I would like for you to describe, out loud, what you are thinking and what you are doing?

**Problem 1**
(A). Predict the product(s) of the following reaction.
(B). Use arrows to show electron flow for this reaction.
(C). Describe in full detail what you think is happening on the molecular level for this reaction. Be sure to discuss the role of each reactant.
(D). Using a molecular level explanation, please explain why this reaction occurs. Be sure to discuss why reactants form the products shown.

\[
\text{HO} + \text{H-Cl} \xrightarrow{\Delta} \text{ products}
\]

**Problem 2**
(A). Predict the product(s) of the following reaction.
(B). Use arrows to show electron flow for this reaction.
(C). Describe in full detail what you think is happening on the molecular level for this reaction. Be sure to discuss the role of each reactant.
(D). Using a molecular level explanation, please explain why this reaction occurs. Be sure to discuss why reactants form the products shown.

\[
\text{Br} \xrightarrow{\text{NaCN, DMSO}} \text{ products}
\]

To be answered after each of the above problems:
1. Now that you have completed the problem, please describe for me how you solved the problem. Did you have a strategy for solving the problem?
2. In studying for your last exam, did you prepare for problems like this one? If so, how did you go about studying for problems like this one?
3. What was hard/easy about the problem?
4. How is this problem similar/dissimilar to problems you had to solve on your last exam?

You’ve now been in class for several weeks and you’ve taken several examinations. What advice would you give to a student completing General Chemistry 2 this semester who is preparing to take this course next semester?

During the first interview, you shared your experience taking the course at that point in time. Based on our conversation that day, I have a few additional questions related to what we discussed that I would like to ask:
Before we end the survey, is there anything else about your experience in organic chemistry so far this term that you would like to share.

Thank you!
10/2/2018

Jeffrey Raker, PhD
CITRUS - Center for the Improvement of Teaching and Research in Undergraduate STEM Education
4202 East Fowler Avenue
CHE205
Tampa, FL 33620

RE: Expedited Approval for Initial Review
IRB#: Pro00036606
Title: Learning Strategies in Postsecondary Organic Chemistry Courses

Study Approval Period: 9/24/2018 to 9/24/2019

Dear Dr. Raker:

On 9/24/2018, the Institutional Review Board (IRB) reviewed and APPROVED the above application and all documents contained within, including those outlined below.

Approved Item(s):
Protocol Document(s):
Protocol, Version 1, August 1, 2018.docx

Consent/Assent Document(s)*:
USF Student, V#1, September 19, 2018.pdf
*Please use only the official IRB stamped informed consent/assent document(s) found under the "Attachments" tab. Please note, these consent/assent documents are valid until the consent document is amended and approved.

It was the determination of the IRB that your study qualified for expedited review which includes activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the categories outlined below. The IRB may review research through the expedited review procedure authorized by 45CFR46.110 and 21 CFR 56.110. The research proposed in this study is categorized under the following expedited review category:

(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

As the principal investigator of this study, it is your responsibility to conduct this study in accordance with IRB policies and procedures and as approved by the IRB. Any changes to the approved research must be submitted to the IRB for review and approval via an amendment. Additionally, all unanticipated problems must be reported to the USF IRB within five (5) business days.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

Kristen Salomon, Ph.D., Chairperson
USF Institutional Review Board
Informed Consent to Participate in Research Involving Minimal Risk

Pro # 00036606

You are being asked to take part in a research study. Research studies include only people who choose to take part. This document is called an informed consent form. Please read this information carefully and take your time making your decision. Ask the researcher or study staff to discuss this consent form with you, please ask him/her to explain any words or information you do not clearly understand. The nature of the study, risks, inconveniences, discomforts, and other important information about the study are listed below.

We are asking you to take part in a research study called:

Learning Strategies in Postsecondary Organic Chemistry Courses

The person who is in charge of this research study is Jeffrey R. Raker, Ph.D. This person is called the Principal Investigator. However, other research staff may be involved and can act on behalf of the person in charge.

The research will be conducted at the University of South Florida.

Purpose of the study

The purpose of this study is to better understand how students study and learn in organic chemistry courses.

Why are you being asked to take part?

We are asking you to take part in this research study because you are a currently enrolled in an organic chemistry course at the University of South Florida.

Study Procedures:
If you take part in this study, you will be asked to:

☐ Participate in two 30 to 60-minute audio-taped interviews. Audio-tapes will be destroyed after transcripts of the interviews have been made. Transcripts will be kept for 5 years after the project is completed in accordance with USF Institutional Review Board policy.

**Total Number of Participants**
About 50 individuals will take part in this study at USF.

**Alternatives / Voluntary Participation / Withdrawal**
You should only take part in this study if you want to volunteer. You should not feel that there is any pressure to take part in the study. You are free to participate in this research or withdraw at any time. There will be no penalty or loss of benefits you are entitled to receive if you stop taking part in this study. Decision to participate or not to participate will not affect your student status or course grade(s).

**Benefits**
You will receive no benefit(s) by participating in this research study.

**Risks or Discomfort**
This research is considered to be minimal risk. That means that the risks associated with this study are the same as what you face every day. There are no known additional risks to those who take part in this study.

**Compensation**
You will be compensated with a $15 gift card to the University of South Florida Bookstore for completing each of the two interviews.

If you are a USF faculty or staff person, you will need to complete a tax payer ID form to participate in the study. If you do not want to complete the tax payer ID form, you can still participate in the study; however, if the form is not completed, you will not be compensated.

**Costs**
It will not cost you anything to take part in the study.

**Privacy and Confidentiality**
We will keep your study records private and confidential. Certain people may need to see your study records. Anyone who looks at your records must keep them confidential. These individuals include:

- The research team, including the Principal Investigator, study coordinator, research nurses, and all other research staff.
• Certain government and university people who need to know more about the study, and individuals who provide oversight to ensure that we are doing the study in the right way.

• Any agency of the federal, state, or local government that regulates this research including the Office of Human Research Protection (OHRP).

• The USF Institutional Review Board (IRB) and related staff who have oversight responsibilities for this study, including staff in USF Research Integrity and Compliance.

• The sponsors of this study and contract research organization.

We may publish what we learn from this study. If we do, we will not include your name. We will not publish anything that would let people know who you are.

You can get the answers to your questions, concerns, or complaints

If you have any questions, concerns or complaints about this study, or experience an unanticipated problem, call Jeffrey R. Raker at 813-523-7317.

If you have questions about your rights as a participant in this study, or have complaints, concerns or issues you want to discuss with someone outside the research, call the USF IRB at (813) 974-5638 or contact by email at RSCH-IRB@usf.edu.

Consent to Take Part in this Research Study

I freely give my consent to take part in this study. I understand that by signing this form I am agreeing to take part in research. I have received a copy of this form to take with me.

_____________________________________________ Signature of Person Taking Part in Study  

_____________________________________________ Printed Name of Person Taking Part in Study

_____________________________________________ Date

Statement of Person Obtaining Informed Consent

I have carefully explained to the person taking part in the study what he or she can expect from their participation. I confirm that this research subject speaks the language that was used to explain this research and is receiving an informed consent form in their primary language. This research subject has provided legally effective informed consent.

____________________ Signature of Person obtaining Informed Consent  

____________________ Date
Printed Name of Person Obtaining Informed Consent