CHARACTERIZING THE PROGRESSION OF KNOWLEDGE, BELIEFS, AND BEHAVIORS IN PEER INSTRUCTORS: AN EVALUATION OF THE GENERAL CHEMISTRY TEACHING INTERNS

By

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A dissertation submitted to the

School of Graduate Studies

Rutgers, The State University of New Jersey

In partial fulfillment of the requirements

For the degree of

Doctor of Philosophy

Graduate Program in Chemistry and Chemical Biology

Written under the direction of

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And approved by

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New Brunswick, New Jersey

October 2020

ABSTRACT OF THE DISSERTATION

Characterizing the Progression of Knowledge, Beliefs, and Behaviors in Peer Instructors: An Evaluation of the General Chemistry Teaching Interns

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At the university level, peer instruction has been widely implemented as a means to offer additional resources through mentorship and academic support for courses with high enrollments and/or high levels of attrition. Peer instructors are students themselves who have typically demonstrated a proficiency in the course for which they serve. In the present work, the peer instructors are a part of the Teaching Internship, a credit-bearing program that includes both a training component and a teaching component. Specifically, Teaching Interns, or TIs, receive training in pedagogy and best practices while providing assistance to students in General Chemistry, an introductory-level science course with notoriously high rates of attrition. While the majority of prior research in this area has examined the benefits to the students on the receiving end of peer learning, the work presented in this dissertation places the spotlight back on the peer instructors themselves. Various frameworks, methodologies, and types of data collection are explored and utilized in order to examine the research questions from multiple angles. Chapter 2 provides the context in which these studies took place and outlines the development of the Teaching Internship and the closely-related Certificate in Chemistry Education program. Chapters 3 and 4 present findings from two separate studies on the TIs following a mixed-methods and qualitative approach, respectively.

The results from these chapters demonstrated positive changes in TIs' chemistry content knowledge, learning beliefs, and verbal behaviors, stemming from their participation in the TI program. To add further context, a quantitative approach used in Chapter 5 provided validation for the use of an instrument to quickly and accurately measure deep and surface learning approaches in General Chemistry students. While the findings of this study can be used to inform the instructional practices within the General Chemistry courses themselves, these results may also provide insight as to how the TIs can encourage deeper learning approaches while working with their students. The final chapter in this compilation includes the published work from a cognate project which illustrates the network of the various components of online learning and how this network was implemented in the General Chemistry courses to enable learning through peer-to-peer interactions.

Dedication

This dissertation is dedicated to all of the kids who were never given the chance to live their dreams. May their struggles serve as my reminder to do what is right, always.

Acknowledgements

When the challenges over the last five years seemed insurmountable, I would daydream about writing this section, a practice that served me well.

First and foremost I would like to thank my advisor, Dr. Darrin York, for putting his trust in me and providing me with countless opportunities, both on land and under water. I would also like to thank my thesis committee, Dr. John Taylor, Dr. Ralf Warmuth, and Dr. Susan Albin, for their thoughtful suggestions and enthusiasm throughout this journey, as well as my labmates for their insightful conversations and the numerous shenanigans we have shared. I am forever grateful for the support of Dr. Mary Emenike, whose honesty and wisdom have made me confident and proud to be a woman in STEM, and for Dr. Marc Muñiz, whose encouragement and down-to-Earth mentorship have been invaluable when I really needed it. This work would not be possible without the General Chemistry instructors, who have always treated me as a colleague and trusted me to work with their students. I would also like to extend my sincerest thanks to the Rutgers maintenance and facilities staff for their essential work on campus, as well as the CCB/IQB administrative staff, and Ms. Shaneika Nelson for her endless assistance over the last 11 years.

I thank my mother Laura, for always doing the best she could with what she had and loving nothing more than seeing her children happy. I also thank my big brothers, my first teachers, Rick and Greg. Their (usually) patient lessons, from telling time to learning to drive, have served me well, and I strive to make them proud. And to Mike, who did not get to watch me finish this journey while here on Earth, I am thankful for his cheerfulness and the much-needed comedic relief he brought throughout my life.

I am forever grateful for the love of my husband Tamr, who I met while sharing a hood in Dr. Taylor's Organic Chemistry lab. I cannot adequately express my gratitude for his support as my biggest cheerleader from Day 1, and I thank him for being my travel buddy, cat-dad, centipede slayer, and procurer of 3 a.m. snacks. We were

married six weeks into the Ph.D. program and I look forward to our post-grad life together as Dr. and Dr. Atieh.

I give my love to my childhood best friends, Jess and Veronica, and my sisters-in-law, whose friendship and support have brought so much light to my life over the years. (P.S. Jess – I am so proud of you!) I give special thanks to my hedgehog Hamilton, and my cats, Kali, Chloe, and Fermi, for their tolerance of me as we have spent a lot of time in quarantine together. To I.F., who I am sure will not accept any credit but deserves it nonetheless, I am forever grateful. Finally, I would like to thank my wonderful students, my TIs, for their cooperation in this work and their patience with me as I was learning right along with them.

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Acknowledgement of Prior Publications

The following chapters of this thesis have been accepted for publication or have been submitted for peer-review.

Chapter 3 has been reproduced[1] with permission from the *Journal of Chemical Education*. Copyright 2020 American Chemical Society.

> **Full citation:** Atieh, E. L.; York, D. M., Through the Looking Class: When Peer Leader Learning Attitudes Are Not What They Seem. *J. Chem. Educ.* **2020**, *97* (8), 2078-2090. DOI: 10.1021/acs.jchemed.0c00129

Chapter 6 has been reproduced[2] with permission from the *ACS Symposium Series*. Copyright 2016 American Chemical Society.

> **Full citation:** Atieh, E. L.; Chun, K. L.; Shah, R.; Guerra, F.; York, D. M., Creation of Academic Social Networks (Asns) for Effective Online Elearning Communities. In *Online Course Development and the Effect on the on-Campus Classroom*, American Chemical Society: **2016**; Vol. 1217, pp 109-126.

Chapters 4 and 5 of this thesis have been submitted for publication and are reproduced with permission from the *Journal of Chemical Education* (submitted for publication). Unpublished work copyright 2020 American Chemical Society.

> Atieh, E. L.; York, D. M., Give and Take: Narrowing the Gap Between Theory and Practice of Peer Instructors Over Time. *J. Chem. Educ.* (submitted)

> Atieh, E. L.; York, D. M., Muñiz, M. N. Give and Take: Narrowing the Gap Between Theory and Practice of Peer Instructors Over Time. *J. Chem. Educ.* (submitted)

The contents of Chapter 2 have been published on our website[3, 4] (authored by Emily L. Atieh) and are adapted for use in this thesis.

Chapters 5 and 6 were part of a collaborative effort, as indicated in the citations above. However, the IRB approval, data collection, analyses, text, and figures are the product of my own, with the following three exceptions:

1. AIC data in Table 5.4 were collected by co-author, Dr. Marc N. Muñiz
2. Portions of the description on our logistic regression protocol (Chapter 5, under *RQ1, Part III. Modeling and Predicting Success*) were co-constructed with co-author Dr. Marc N. Muñiz
3. Figure 6.3 was modified from a figure originally created by co-author Dr. Francesca Guerra

Chapter 1 | Introduction

As the first doctoral student in chemistry education at Rutgers University, my research incorporates different methodologies to examine various aspects of learning among two interconnected populations. The overarching goal of this work was to implement and evaluate a peer instruction program within General Chemistry, a course sequence required by nearly all Science, Technology, Engineering, and Mathematics (STEM) students. Built on the theories of constructivism[5] and tutor learning,[6] the underlying hypothesis was that peer instruction is not only a resource that improves with scale, but that it serves to benefit both the students and the peer instructors alike. By playing a central role in both the teaching and research of this project, a feedback loop could be established that would both inform my teaching practices as well as my research design.

In the following chapter, a thorough description of two programs, the Certificate in Chemistry Education and the Teaching Internship, are provided. Chapter 3 presents the results of a mixed methods study that investigated the Teaching Interns' beliefs about learning chemistry and the ways in which those beliefs changed throughout their time in the TI program. In Chapter 4, a qualitative study is conducted to characterize the verbal behaviors of TIs as they interact with students. The purpose was to measure the gap that exists between a TI's beliefs about effective teaching and what practices they actually use. The results from both of these two studies can be used to inform peer instruction training and pedagogical training in general. Chapter 5 presents the results of a quantitative study in which a model was constructed to predict General Chemistry students' course outcomes based on their deep and surface learning approaches. These approaches are rooted in Meaningful Learning Theory[7] and were partially motivated by Chapter 4's exploration of deep and surface knowledge-sharing during TI-to-student discourse. The final chapter is a supplemental project and discusses the use and implementation of various online course components within General Chemistry. These components form the basis of a larger network and stem from several of the same tenets of peer instruction and the facilitation of deep learning, including social constructivism and self-regulated learning.

Chapter 2 | The Certificate in Chemistry Education and Teaching Internship Programs

The Implementation of Peer Instruction at Rutgers University

Research Motivations

This purpose of this chapter is to outline the structure of two distinct peer instruction programs that I have worked to build, implement, and evaluate during my doctoral research. These are the Certificate in Chemistry Education (CCE) program and the Teaching Internship (TI) program. The foundation for both of these programs rests on an amalgam of prior literature, basic theories of learning, and my own knowledge and experience from my previous graduate work. In fact, my research interests in this area originated in part from my own experiences as a former struggling chemistry major, an undergraduate laboratory instructor, and a graduate teaching assistant in an inquiry-based physics course. Each of these experiences were filled with challenges and even discomfort, but they provided me with a unique perspective that helped to shape the research presented in this thesis.

Broadly, my proposed research set out to examine the changes that TIs undergo as a direct result of their role as a peer instructor. Given this objective, I opted to take on an immersive role in this work, as it would enable trust with my research participants, allow me to implement changes quickly if needed, and ultimately provide the contextual information needed when interpreting the results of qualitative research. As such, I took on the role of instructor and coordinator for both of these programs.

Design and Management of the TI and CCE Programs

Just prior to beginning the doctoral program in the Fall of 2015, I had written two separate IRB applications with the intent to study the TIs in both programs as well as the General Chemistry population for which they serve. These applications were both approved in the days leading up to the Fall 2015 semester. In addition to approval for conducting research, these programs and the affiliated courses had to undergo review and approval by faculty in the Rutgers Department of Chemistry and Chemical Biology, the Undergraduate Curriculum Committee, and the deans of the School of Arts and Sciences Honors Program (and later the Honors College).

The first task centered on building the programs via the recruitment of potential TIs through advertisement, the review of 100+ applications, the execution of 12 separate group interviews over the course of one week, and the evaluation and selection of the TIs themselves. Course topics, assignments, grading policies, and lesson plans were the next step in ensuring that the TIs received proper training. As their instructor, I taught three separate weekly TI training meetings to accommodate the 40-50 TIs each fall and spring semesters, on top of teaching the CCE program's Pedagogy Course, *Introduction to Chemistry Education* in the fall semesters. Likewise, this role inevitably led to my involvement in several of the components of the General Chemistry courses, such as teaching in the recitations. This teaching schedule continued from the Fall of 2015 until the Spring of 2019. In addition to the instructional requirements, both programs required the coordination of 60+ TIs' schedules while remaining mindful of the needs of the General Chemistry students and instructors. Reserving space, managing scheduling, and advertising the supplemental help sessions offered by the TIs were the main on-going duties while serving in this role.

My immersion in this research study became inevitable as my relationship with the TIs took many forms: coordinator, instructor, researcher, mentor, and eventually, colleague. Through the evolution of these roles, I was able to build a learning environment that prioritized trust and safety. This investment proved worthwhile, as it facilitated honest dialogue between myself and the TIs, as evident in their reflection posts, research interviews, and surveys.

Moving Forward

Upon termination of my non-research roles in these two programs, two instructors stepped in to observe my final semesters working with the TIs and students, enabling a smooth transition. Both of these programs have since continued to grow and evolve to suit the needs of the student. Such flexibility has been most notable in recent semesters as the SARS-CoV-2 pandemic forced students into an online learning environment and necessitated a closer look at student engagement. These programs have cemented themselves into the General Chemistry curriculum and played a key role in shaping the culture of active learning and course reform within the department.

The Certificate in Chemistry Education Program

Overview

The Certificate in Chemistry Education (CCE) is a credited, comprehensive peer instruction program that provides undergraduate students with formal pedagogical training, professional development opportunities, and broad experience in teaching chemistry.[3] The CCE program encompasses multiple upper-level courses and offers students in the Honors Program/Honors College two options for incorporating this work into their Honors requirements. These components and options are illustrated in Figure 2.1. All undergraduate students invited to the CCE program may also opt to participate in any of the individual components of the CCE independently.

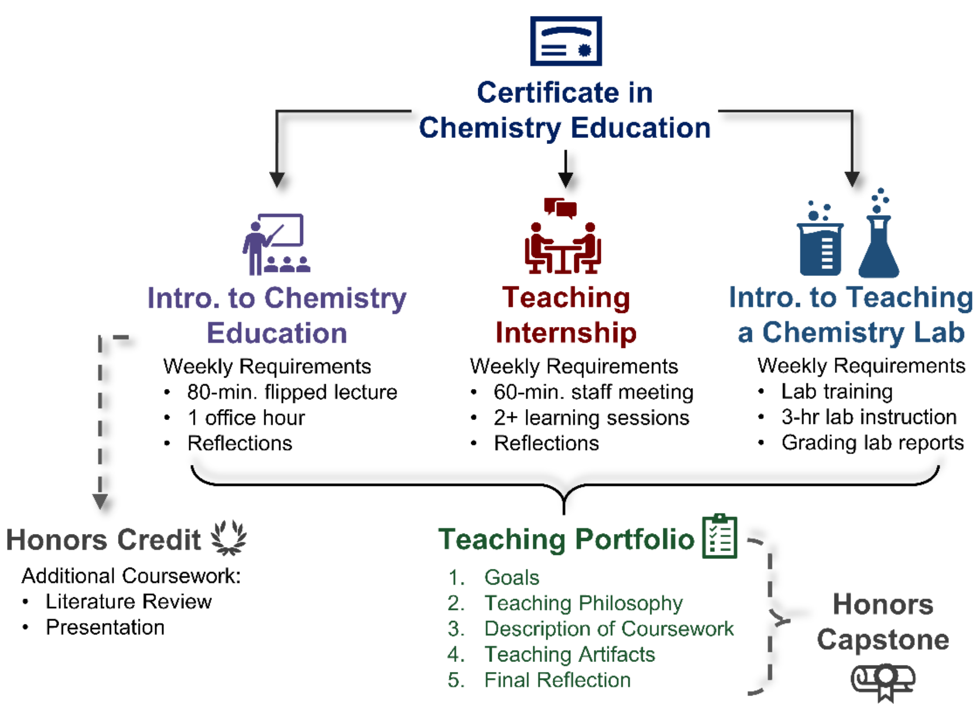


Figure 2.1. A summary of the requirements for students enrolled in the Certificate in Chemistry Education program. Two separate options are offered students in the Honors Program/Honors College.

Introduction to Chemistry Education (3 credits)

Also referred to as the Pedagogy Course, *Introduction to Chemistry Education* serves as an introduction to pedagogy and research in chemistry education and related fields. The course has two distinct components: (1) One 80-minute class per week and (2) One 60-minute office hour per week for General Chemistry students. These elements work together as a feedback loop between educational theory and practice, as this course is intended to prepare TIs for the later requirements of the CCE program. A sample syllabus for the course, including topics and assignments, can be found in Appendix B.

Teaching Internship in Chemistry (2-3 credits)

The Teaching Internship (TI) program is offered each semester for both General Chemistry and Organic Chemistry.[4] TIs in the CCE program may take 1 or 2 credits per semester; however, it is highly recommended that first-time TIs take only 1 credit in their first semester. Exceptions may be made on a case-by-case basis, particularly for non-traditional students and students entering the CCE program as upperclassmen. All CCE participants must serve as a TI for General Chemistry courses for at least 1 credit.

The General Chemistry and Organic Chemistry TI programs operate slightly differently from one another in order to suit the individual course's needs. TIs receive weekly training and work regularly with students by assisting in recitations or lectures, or by hosting office hours, workshops, and other active learning opportunities. Experienced TIs who have demonstrated outstanding dedication and responsibility may have the opportunity to take on a leadership role, such as a Head TI, and work closely with the TI program coordinator on other aspects of the program. Further details on the TI program in General Chemistry can be found in the following sections of this chapter.

Introduction to Teaching Chemistry Lab (3 credits)

The *Introduction to Teaching a Chemistry Lab* course provides training and support for upper-level undergraduate students acting as primary instructors in the General Chemistry laboratory course, called *Introduction to Experimentation*. Undergraduate instructors are fully in charge of one section of the lab. Although the entire laboratory course is managed by a professor, the undergraduate leaders are the only instructors present in the lab at any given time, aside from stockroom personnel. The undergraduate lab instructor's responsibilities include ensuring student safety in the lab, demonstrating proper lab protocol for each experiment, assisting students during the lab time, and grading of their students' lab reports. Each instructor leads their own 3-hour section of the lab each week. Additionally, they attend a weekly training session to perform the upcoming week's laboratory experiment and brainstorm potential student difficulties under the supervision of a graduate Teaching Assistant.

Eligibility and Selection Process

The CCE program is offered by invitation-only and is open to undergraduates of any year following a successful performance in General Chemistry. However, earning an "A" is not necessarily required, and students who experience personal challenges with their own coursework may be better equipped to empathize with their colleagues and provide guidance as to how they were ultimately able to succeed. Both semesters of General Chemistry serve as a pre-requisite for this course and may not be taken as a co-requisite; however, transferred and Advanced Placement credits are acceptable replacements for General Chemistry I.

Students may choose to become a TI either as a part of the Certificate in Chemistry Education (CCE) Program or independently; however, the selection process for both is identical. Following the results of the second midterm in General Chemistry II (usually around mid-March), students who demonstrate proficiency in both semesters of General Chemistry receive an invitation to apply for the TI program. The application mainly consists of questions regarding students' general information (e.g. major, GPA, coursework, etc.) in addition to 2-3 short-answer questions about the applicants' experiences in General Chemistry and schooling in general.

Students selected from this pool are invited to group interviews in which they work with 2-4 other applicants. These groups are expected to work collaboratively to complete multiple short activities focused on both interpersonal and intrapersonal qualities (such as confidence, communication, and conflict-management), as well as the application of chemistry content knowledge to various teaching scenarios. After a designated amount of time, each group is given the opportunity to present their conclusions. Current TIs and instructors assist the coordinator in the observations of the applicants and provide their assessments following the interview. Examples of the different types of interview activities, as well as the rubric used for assessment can be found in Appendix B of this work.

Teaching Portfolio

The coursework components of the CCE program are joined together via the creation of a teaching portfolio. This portfolio is a collection of written pieces developed and revised by the CCE TIs over the course of their time in the program. Upon completion of the course requirements, CCE graduates retain this portfolio as tangible evidence of their professional development, mentorship experience, and leadership abilities. The teaching portfolio consists of five main components:

1. A Goals
2. Teaching Philosophy
3. Coursework Descriptions
4. Relevant Artifacts
5. Final Reflection

Following each semester in the CCE program, these works are updated as needed and are submitted to the CCE coordinator for review. A committee comprised of professors and the TI/CCE coordinator(s) review the final portfolio prior to the student's graduate date. Upon acceptance of the final work, the university acknowledges the completion of the program and awards the student with the certificate.

Honors Track

TIs in the Rutgers Honors College/Honors Program may elect to participate in the Honors Track. This track is two-fold and Honors TIs may choose one, both, or neither of these options.

In the first option, TIs receive Honors Designation for the *Introduction to Chemistry Education* course. Honors students are required to take four 3- or 4-credit elective courses that are designated as Honors courses. Honors TIs enrolled in the Pedagogy Course may elect to receive Honors designation for this course prior to the first day of class. Both Honors and non-Honors TIs will meet at the same time and place, work together, and complete identical coursework; however, the Honors TIs must also complete two additional assignments. The first is a short literature review on a topic of their choosing related to pedagogy, inclusion and diversity, or chemistry education. In the second assignment, Honors TIs develop a 15-20 minute presentation to discuss their findings from their literature review using any format of their choosing.

In the second Honors option, TIs may elect to use the CCE program itself as their Honors Capstone project. All students in the Honors College/Program must complete a capstone project by the conclusion of their undergraduate degree. Following discussions with the curriculum committees and deans, the CCE program was classified as a viable option for the capstone.

The Teaching Internship

Purpose and Framework

The Teaching Internship (TI) program in General Chemistry is a peer instruction program that provides undergraduates with experience in assisting students in General Chemistry. Taken as a credit-bearing course, the TI program includes weekly training sessions (i.e. staff meetings) led by the TI coordinator, in addition to supplemental learning sessions with current General Chemistry students. TIs are not expected to be content experts in the same way as a professor, nor do they need to have prior experience in tutoring or public speaking.

The TI program is rooted in the theories of social constructivism, which states that people gain knowledge and skills through social interactions with others.[5] In this sense, TIs serve as facilitators, assisting students in the purposeful construction of their own knowledge in order to form meaningful conceptual connections. The following goals serve as a guide for the overall structure and management of the program:

1. Interns will further deepen and learn to apply their General Chemistry content knowledge to novel situations in order to assist current students in the course
2. Interns will improve upon their teamwork and communication skills by working with each other, as well as with General Chemistry students
3. Interns will improve upon their metacognitive skills (self-monitoring, self-evaluating) through student interactions, weekly reflections, and class discussions.
4. Interns will apply pedagogical knowledge and best practices from the weekly training meetings to their learning sessions with General Chemistry students.

Eligibility and Selection Process

The eligibility and selection process of the Teaching Internship is identical to that of the Certificate in Chemistry Education (CCE) program. Please see the previous section for details on the pre-requisites and application/interview procedure.

Weekly Training Meetings

Each week, TIs attend a 1-hour training meeting facilitated by the TI coordinator. These sessions allow TIs to work together, share experiences and advice, and ask questions or seek support for any situation that may arise during their learning sessions. Training consists of hands-on activities that relevant General Chemistry topics with various best practices in teaching. Some of the most common practices discussed in the weekly meetings include:

1. Effective questioning techniques
2. Diversity and inclusion in education
3. Common misconceptions (or alternate conceptions) in General Chemistry
4. Using analogies in chemistry
5. Improving communication/public speaking skills

A sample activity for Item #3, alternate conceptions, can be found in Appendix B.

Learning Sessions

TIs work with General Chemistry students on a regular basis throughout the semester, typically meeting more than once per week, although the exact schedule depends on the type of learning sessions selected and the number of credits taken. Learning sessions can range from small, individual office hours to facilitating large recitations and lectures alongside other TIs and professors. Table 2.1 provides a description of the various types of sessions.

Table 2.1. Description of the Potential Learning Sessions for TIs to Conduct

Session	Description
Office Hours	• Clustered into large blocks of time (typically 6 hours, on average) • A single session for a TI is 1 hour • "Walk-in" hours: students may come at any time during the reserved times and do not need an appointment • TIs can prepare by keeping up with the textbook readings and homework
Workshops	• Small-group learning session (12-15 students) focused on a specific topic, which students must sign up for in advanced • Two TIs run a single workshop • TIs are in charge of developing activities for students to work on in groups
Active Learning Recitations (ALR)	• Face-to-face recitations in which students work in small groups to solve open-ended activities prepared by the professors • Approximately 4-6 TIs work alongside a professor in a single ALR • TIs must attend ALR staff meetings with the professor(s) to complete the recitation activity and offer feedback prior to the ALR itself
Lecture Break-Outs	• TIs help to facilitate break-out greats in large lectures • Multiple TIs facilitate a single lecture • TIs must attend staff meetings with the course professors to discuss the assigned activities and provide feedback prior to the lecture.
Review Sessions	• Large (150+) review sessions to prepare for pending exam • Two TIs run a single review session • TIs should prepare some material ahead of time to initiate dialogue, but should focus on encouraging students to ask their own questions
Virtual Office Hours	• Online video office hours using the course learning management software • Typically held during the evening hours to accommodate commuters and non-traditional students. Students may log in at any point during the office hour to ask questions. • TIs can prepare by keeping up with the textbook readings and homework and ensuring they have adequate internet connections
Head Teaching Intern	• A group of 2-3 experienced TIs who assist the TI coordinator with program logistics, content development, and leading 1-2 TI training sessions per semester • Head TIs meet with the TI coordinator once per week • These Head TIs should enroll for 2 credits of the program, such that they are also having weekly interactions with General Chemistry students

Weekly Reflections

TIs keep an online reflection blog on the course management website, which is accessible to all other TIs in the course. Each week, TIs submit their reflection, in addition to a comment on another TI's post, typically to offer advice, feedback, or other insights. Semi-guided reflection prompts are developed by the TI coordinator each week and posted for TIs to follow. Primarily, the reflection prompts encourage the TIs to discuss their personal main takeaways from both the weekly meetings and from their learning sessions. Miscellaneous questions are often included as well in order to monitor TIs' general progress or beliefs, or to serve as a space for TIs to express other emotions and thoughts. These questions were initially intended to serve as a mechanism for informing future training topics, as they provide direct access to the TIs' prior knowledge and beliefs. However, data collected from these questions resulted in a valuable repository of data that motivated several of the research questions found in this thesis.

Chapter 3 | Through the Looking CLASS: When Peer Leader Learning Attitudes Are Not What They Seem

Abstract

The Teaching Internship is a credit-bearing program comprised of undergraduate near peer instructors (Teaching Interns, or TIs) that offers supplemental assistance for students in the General Chemistry courses. With fellow undergraduates serving as a role model and student-faculty liaison, the benefits of near peer instruction have been well-documented. Because TIs develop a dual role of student and instructor over time, they afford a unique opportunity to explore the middle area of the expert/novice spectrum. Identifying the most influential components of the TI role may allow practitioners to implement these components in other ways for different groups of students. The present work provides a description of the TI model and uses a mixed-methods approach to analyze how the peer leadership role impacted the TIs' attitudes about learning chemistry. Quantitative results show that TIs do hold predominantly expert-like learning attitudes compared to the General Chemistry population from which they are selected; however, evidence of novice thinking is still observed in some areas. This survey data was then used to inform a qualitative approach. Further analysis indicated that TIs' responses on survey items were context-dependent, and that peer leadership experiences were associated with expert learning attitudes and appear to be influential in the development of these attitudes. These findings suggest that these factors should be taken into account when drawing general conclusions from survey results.

Introduction

Rising university enrollments in the STEM fields have outpaced the moderate growth in higher education funding,[8, 9] leading to increasing concerns about sustainability and student learning.[10-14] Recent calls for a larger, more diversified STEM work force highlight the need for educational reforms.[15] So-called "near peer" instruction has been one means for mending the resource gap, cementing itself as a critical component of the teaching and learning infrastructure in higher education. Previous studies have demonstrated the many benefits to students on the receiving end of near peer instruction,[16] but fewer studies have reported the impact on the peer instructors themselves.[14]

The present study aimed to quantify and describe how the peer leadership role in the Rutgers General Chemistry Teaching Internship program has influenced the teaching interns' (TIs') beliefs about learning in real time. Our original strategy was to explore the use of the Colorado Learning Attitudes about Science Survey (CLASS),[17] an instrument that has been validated and used in other contexts. We found, however, that the TIs' responses were highly context-dependent, and delving deeper, we collected extensive qualitative data that shed light on the origin of novice and expert shifts in attitudes. We found that TI shifts towards expert attitudes were most profoundly correlated with their experience as a peer leader; in fact, there were no instances in which novice shifts in attitude were associated with this context.

The paper is outlined as follows: The next section provides a brief summary of the relevant literature on peer and near peer instruction, as well as the motivation for this work. Following, a description of the TI program establishes the context of the study and the key research questions are developed from a framework of situated learning. The Methods section provides a detailed description of the datasets collected and their analysis. The Results and Discussion then presents the analysis in order to sequentially answer each research question outlined earlier. The paper closes with a summary of limitations, overarching conclusions, and implications for researchers and practitioners.

Literature Review

Defining (Near) Peer Instruction

A quick search of the literature shows that peer instruction and its close relative, near peer instruction, are becoming a standard practice within higher education.[16] Cited as a means to compete with increasing admissions and changes to the student populations,[16, 18-20] it also serves as an homage to the shift towards active learning.[21-24] Peer instruction was first named by Eric Mazur as a means of engaging all students in large-enrollment courses.[25] In lecture, students explained their reasoning for a given conceptual problem (a Concepts') to others in their vicinity. The "peers" are other students enrolled in the class. Near peers, on the other hand, are experienced students who have successfully completed a course and return to teach current students. Murphey first coined the term "near peer," describing them as "…peers who are close to one's social, professional, and/or age level, and whom one may respect and admire."[26, 27]

Singh outlines some of the major differences between peers and near peers in her commentary, primarily contrasting students' perceptions of their peers versus their near peers.[28] Still, the two terms are often used interchangeably in the literature, with both falling under the "peer" umbrella, and countless nuanced terms only add to the confusion: peer mentor,[20] peer tutor,[29] peer assistant,[23] peer facilitator,[30, 31] peer leader,[32-34] etc., in addition to others (e.g. undergraduate teaching assistant,[35-39] learning assistant,[40] teaching intern,[32] etc.). Even within a given term, the duties or goals of these peers/near peers can look vastly different between departments, universities, and disciplines.

Such inconsistent use of terminology in the literature can lead to a considerable lack of clarity in discussions. For the purpose of this paper and the various programs described, we define "peer leader" as follows:

> An undergraduate student acting in a mentorship or instructive role for other undergraduate students in a course or program for which they themselves were previously enrolled.

The authors felt that the term "peer leader" was most inclusive, consistent with current literature, and properly conveyed the experience and facilitative nature of the students acting in these roles.

Peer Leadership: History and Outcomes

In the 1970s, sudden demographic changes, climbing attrition rates, and scarce resources catalyzed a movement that resulted in the earliest standardized model of peer leadership: Supplemental Instruction, or SI.[11, 41] Deanna Martin, a doctoral student at the time, proposed the SI model as a stark contrast to previous remedial-focused efforts that were being phased out nationwide.[11, 42] Later programs like Peer-Led Team Learning (PLTL)[24] and the Learning Assistant (LA) Program[40] further helped to popularize the idea of peer leadership in the 90s and early 2000s. There have since been countless models of peer leadership described in detail in the literature and implemented nationally and internationally.[14]

In accordance with the expansion of this practice, numerous researchers have examined the outcomes of peer leadership in courses such as physics,[43, 44] computer science,[45] engineering,[46, 47] chemistry,[19, 22, 48-51] social sciences,[18, 38, 52] life sciences and medicine,[21, 35, 39, 53, 54] and the humanities.[55, 56] Emerging benefits include both content gains (pass rates,[19] retention,[49] and exam scores[40, 48, 49]) and non-content gains (attitudes[49, 50] and communication skills[57]) for students served by peer leaders. However, only a handful of studies have aimed to characterize the effects of peer leadership experience on the peer leaders themselves. Such effects can also be classified as content-related, including higher course grades,[20, 51] improved content knowledge,[32] or perceived improvement in content knowledge,[33, 34, 45, 51, 58] as well as non-content related, such as improved confidence[30, 33-35, 58] and development of leadership,[32, 33, 58] communication,[45] and teamwork skills.[33, 34, 45] Beyond content knowledge and intra- and interpersonal skills, there was a dearth of research on students' beliefs specifically about learning chemistry. Moreover, several of these studies examined subjects' self-perceived gains after their completion of the program through course/program evaluations or other open-ended surveys.[33-35, 45, 51, 58] In this paper, data is collected to measure changes as they occur over time, in conjunction with reflective data, to further elucidate the direction and cause of change.

Learning Beliefs in Chemistry

As a whole, student beliefs about science have largely been correlated to their success and retention in the class and in STEM.[17, 59, 60] For example, beliefs about identity and belonging in a field have historically been linked to success and persistence in STEM, particularly for underrepresented students.[61-63] Moreover, beliefs about learning in STEM (metacognition, epistemology, the scientific process, relevance of science to the real world) are unsurprisingly different between novices and experts.[64-66] Such research characterizing the dichotomy between novice and expert learning have underscored the push for students to "think like a scientist" and develop skills needed for the modern world.[67]

Peer leaders serve as a liaison between faculty and the students they work with, and are often high-performing students themselves, providing reasonable cause to place them at some midway point on the novice-expert spectrum. Concerning content skills such as problem-solving, the differences between novices and experts is evident: experts classify problems according to underlying principles ("deep structures"), whereas novices tend to use surface features.[68, 69] Experts are better at focusing their attention on important details of a problem and are more likely to perform certain tasks automatically.[70-72] Further, studies have shown that those in between novices and experts display some characteristics of both.[69, 73] Beyond problem-solving, previous work has linked instructional methods and curriculum design to students' beliefs, attitudes, or epistemological development, also often in the context of expert versus novice thinking.[17, 74-77] For example, Otero and Gray[75] found expert shifts using the CLASS in their physics and physical sciences courses for nonmajors, following a curriculum change that explicitly addressed the nature of science and science learning. In this study, investigating the affective transformations of peer leaders, who likely sit somewhere between experts and novices, means gaining better insight into the novice-expert shift and even pinpointing the experiences that shape scientific thinking. In the next section, we will describe the implementation of the Teaching Internship program in order to provide a thorough context for the present research study.

The Teaching Internship in General Chemistry

The General Chemistry Teaching Internship program was implemented in its current form in the Fall of 2015.[4] The internship is a for-credit course, as TIs are not paid a stipend and must register as they would for any other course. New TIs are invited to apply to the program each year based on their performance in General Chemistry I and II. While they primarily earn top grades in the course, an "A" is not strictly required. Selection then follows small group interviews. Generally, TIs of previous years are permitted to return each year as they choose, and many do. The weekly course requirements are provided in Table 3.1 and include a staff meeting with the program coordinator (E.L.A.), multiple learning sessions with students (office hours, recitations, workshops, etc.), and semi-guided written reflections that are accessible to all TIs. More details about the selection process and program components can be found in the Supporting Information.

Table 3.1. Certificate in Chemistry Education (CCE) Coursework and Requirements

Course	Length (Semesters)	Credits per Semester	Weekly Requirements
Introduction to Chemistry Education (Pedagogy Course)	1	3	Flipped Class: 80 min One Learning Session: 1 hour Written Reflection
Teaching Internship	2+	1-2	Staff Meeting: 1 hour Multiple Learning Sessions: 2-4 hours Written Reflection
Teaching a Chemistry Lab	1+	3	Lab Training: 3 hours Teaching: 3 hours

The Certificate in Chemistry Education (CCE)

For applicants who wish to become more involved in peer leadership, they are encouraged to apply for the Certificate in Chemistry Education (CCE) program (Table 3.1).[3] The required Pedagogy Course (PC) is a flipped-style 3-credit course created and taught by E.L.A, and includes both weekly teaching and classroom components. As these students work with General Chemistry students, they are also referred to as TIs, with the two groups differentiated as PC- and non-PC TIs. The course covers topics similar to the TI staff meetings; however, students in the PC source their knowledge from the assigned literature, delving deeper into the theories of education, and complete frequent assessments.

Following the PC, CCE participants enroll in the TI program, followed by leading their own section of the General Chemistry labs. In an effort to maintain inclusivity for students facing a semester of abnormally rigorous coursework, health challenges, or other unexpected circumstances, the CCE program can be flexible and non-linear. For example, a small set of TIs applied to the TI program initially, and later opted to take the PC.

Framework: Situated Learning Through Teaching

The notion of teaching as a means for learning can be found throughout the education literature,[78-80] largely stemming from the pivotal work of Benware and Deci.[81] In their study, students performed better on an assessment when they believed they would teach the material, compared to those who believed they would be taking a traditional exam. Shook and Keup[14] write that peer leaders develop the abilities to combine and apply multiple skills to solve realistic, ill-structured, multi-faceted problems – abilities often attributed to experts.[68, 82-85] Given that student attitudes are tied to their problem-solving strategies[83, 86] and performance in the class,[87, 88] it is plausible that peer leaders also experience expert shifts in their beliefs about learning chemistry.

Situated Learning

Situated learning theory refutes the notion of knowledge as an entity to be gained by an isolated learner. Instead, it holds that knowledge gained is a result of some external interaction(s).[89] As a theoretical framework, situated learning addresses how learners interact with their environment, create meaning via social interactions, and achieve "old-timer" status in their community of practice (the TIs) via legitimate peripheral participation (teaching in their learning sessions).[90] As such, in an effort to study the TIs as a community of practice, it made sense to differentiate the experienced TIs (the "old-timers") from the newcomers in our analysis to understand the role that experience plays in shaping learning attitudes. Similarly, analysis should also consider the fact that the PC offers a different learning environment compared to the TI program alone. These decisions served as the pre-requisite research questions (RQ1 and RQ2, below) needed to answer our primary question, RQ3. While surveys are not the traditional method associated with the situated learning framework, survey data was crucial in informing the qualitative approach used for RQ3. Such methods were then evaluated as RQ4 emerged during data analysis.

Research Questions

The research questions developed were as follows:

1. Do peer leaders' beliefs about learning chemistry correlate to their length in the program?
2. Do peer leaders' beliefs about learning chemistry correlate to whether or not they enroll in a formal Pedagogy Course?
3. Do peer leaders' beliefs about learning chemistry change over time as a result of their peer leadership experience?
4. Is the CLASS a valid means for assessing the beliefs of peer leaders?

Methods

Setting

Rutgers is a large, R1 university and the state's only public land-granting university. This study was conducted on the main New Brunswick campus which hosts 36,000 undergraduate students and 14,000 graduate students.[91] Approximately 2,000 students enroll in General Chemistry each semester. Nearly three quarters of these students are life science or pharmacy majors, followed by a minority of physical science and social science majors. Nursing and engineering students each have their own version of the course, which is not served by the TIs. The General Chemistry courses include traditional lectures (~300-400 students each), common-hour exams, and graded online homework.

Participants

TIs are selected from the General Chemistry course population which they will serve. Their declared majors are provided in Figure 3.1, along with demographic data that contrasts them with one cohort of General Chemistry students.

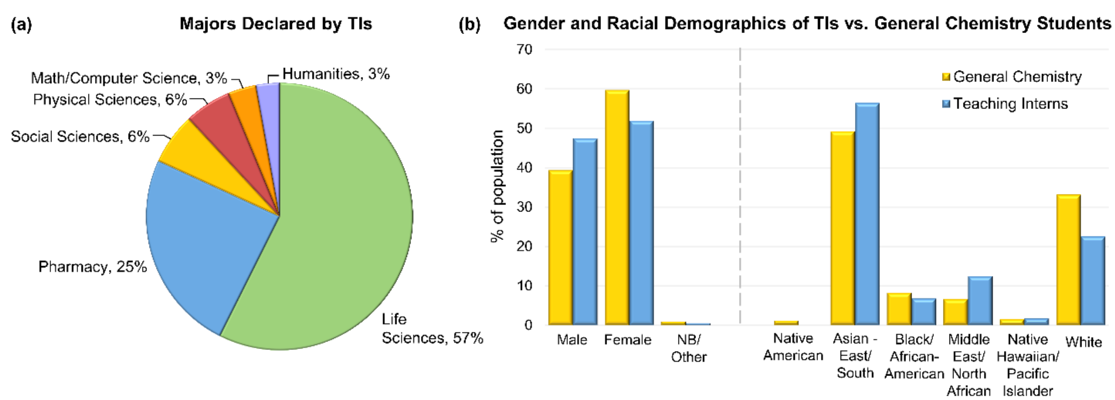


Figure 3.1 (a) The reported majors of all TIs from Fall 2015 - Spring 2018 as a percentage (N=179; 2 TIs reported double-majors). (b) The gender and racial make-up of General Chemistry students (Fall 2015; N=1,510) and Teaching Interns (Fall 2015-Spring 2018; N=177). Please note that the gender abbreviation "NB" refers to "non-binary".

The Colorado Learning Attitudes about Science Survey (CLASS)

Beginning in the Fall of 2015, TIs were asked to complete the chemistry version of the CLASS.[92] The CLASS was originally designed for assessment in physics, but it was later adapted and validated for use in chemistry.[93] The CLASS-Chem provides 50 statements about chemistry and learning, and participants use a five-point Likert scale to note their level of agreement or disagreement. Instructors can then classify students' responses as evidence of "novice" or "expert" beliefs. Expert consensus has been established in previous work for forty-five of these statements,[17, 92] meaning experts (e.g. physics professors) converged on their level of agreement for these statements. Thirty-six of these statements belong to one or more of the nine previously-established categories to help provide meaning to the responses.[92] These categories are provided in Figure 3.2 and described in detail in the Supporting Information. Several of the CLASS items fall under multiple categories, and Figure 3.2 demonstrates the relative amount of overlap between categories; larger circles contain more items, and the larger the overlap, the more items those categories share. Each category has a favorable and unfavorable section, which represent the percentage of statements by which students agreed or disagreed with the experts, respectively. Neutral responses are excluded from the scoring. Various measures are taken to flag responses that may not be genuine (See the Supporting Information, Section V).

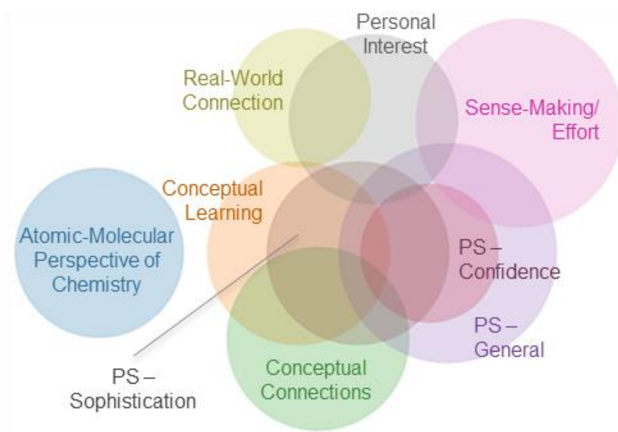


Figure 3.2. A Venn Diagram displays all nine categories of the CLASS. "PS" is shortened for "Problem Solving." The size of the circle corresponds to the number of items in that category; the size of the overlap refers to the number of items that sit in two or more categories. The PS-Sophistication and PS-Confidence categories have only items that also live in other categories, while the Atomic-Molecular Perspective of Chemistry items exist entirely in their own category.

The TIs complete the CLASS as a pre- and post-test in the beginning of the fall semester and at the end of the spring semester, respectively. Thus, students who have been TIs for multiple years have completed the survey more than twice. TIs who only remained in the program for one semester did not complete a post-test and are excluded from the results. TIs enrolled in the PC, offered only in the fall, are also given a post-test at the end of the fall semester. Data was collected for three academic years, as shown in Table 3.2.

Table 3.2. TI Enrollment by Academic Year

Academic Year	TI Status	Fall – PC	Fall – TI Only	Spring – TI Only
2015-2016	New	11	27	34
	Returning	6	7	4
2016-2017	New	12	20	25
	Returning	1	20	11
2017-2018	New	13	20	24
	Returning	2	22	14

A myriad of instruments have been developed for measuring chemistry students' attitudes, beliefs, expectations, self-concept, epistemologies, and so on.[92, 94-99] While there are important differences between these constructs, such analysis is beyond the scope of this paper and has been discussed previously.[94, 100, 101] The decision to implement the CLASS over other assessment tools came down to practicality and applicability. The CLASS did not refer to a specific course or course component, such as a lab, which would have been inappropriate for our sample. Likewise, a homogenously high performing population may have negated the usefulness of a self-concept measurement.[102]

While overlapping categories within the instrument have brought the discriminant validity of the CLASS into question,[103] the categories themselves were of secondary importance. The CLASS items best aligned with the intended research questions, and the plan to conduct further investigation beyond the survey would provide additional meaning behind the quantitative results.

Non-parametric statistical tests were performed in SPSS to analyze survey data, after a Shapiro-Wilk test showed that the results were not normally-distributed. Specifically, the Wilcoxon signed-rank test was used to identify large shifts in TIs' matched pre- and post-test scores. Due to sample size concerns, the test was performed using exact calculations (as opposed to asymptotic). Effect sizes are reported as rank-biserial correlations, *r*.[104] A detailed description of these calculations can be found in the Supporting Information.

Interviews

Because the CLASS had never been used on this population, we felt that conducting interviews would provide insight as to how these participants were interacting with the instrument. A stratified sample of 13 TIs were selected to participate in an interview (Table 3.3). TIs were sorted by gender, PC enrollment (or lack thereof), and year in the TI program. TIs were then randomly selected from these categories where possible.

Table 3.3. Interviewee Profiles

Pedagogy Course	Gender	1st Year*	2nd/3rd Year*
Completed	Female	Zara Manasi	Marla
	Male	Niven Raj	
Did Not Enroll	Female	Nanjana Emma	Reema
	Male	Sami George Ronit	Kenny Darsh

*Names have been changed

The interviewee's collective CLASS responses were used as a rough interview guide. To prepare for each individual interview, the interviewer (E.L.A.) noted items that had large shifts, novice responses, or responses that differed from the majority of the other TIs. The interviewer asked TIs to recall their responses and consider their reasoning, particularly stating what context they were thinking about when they selected their answer. Interviewees were given a physical copy of the CLASS instrument but not their responses. To minimize bias, the interviewer did not make any references to the TI/CCE programs until the final question, unless it was first prompted by a TI. Audio data was collected, transcribed, and coded using NVivo version 11.

IRB Approval

All methods and procedures were granted IRB approval from the university, under IRB protocol 15-813M, with annual renewal.

Results

RQ1: CLASS by Year in Program

To measure the attitudinal changes that take place over time in the program, it seemed logical to look at the TIs' scores based on their number of years in the program. Matched data from all first- and second-year TIs were separated. While some TIs had completed three years in the program, the sample size was too small (N=7) to obtain meaningful results. Data collected during a TI's enrollment in the Pedagogy Course were excluded. To check for possible inconsistencies between academic years, a Kruskal-Wallis test was run to compare scores between the three academic years for both groups. No significant differences were found, supporting the decision to combine all first-year TIs into one group and second-year TIs into a second group.

Figure 3.3 shows a large, expert shift in the "All Categories" section for first-year TIs. Large shifts also appeared in three of the categories: Real World Connection, Atomic-Molecular Perspective of Chemistry, and Conceptual Connections. The first two categories saw shifts in the expert direction, with the Atomic-Molecular Perspective of Chemistry category demonstrating both a significant gain in the favorable responses (F) and loss in the unfavorable responses (U). However, the Conceptual Connections category saw a novice shift due to the rise of the unfavorable score. Effect sizes were calculated using a rank-biserial correlation, r. Figure 3.3 illustrates these changes and provides the effect sizes. Exact scores and shifts can be found in Table 3.S1 in the Supporting Information.

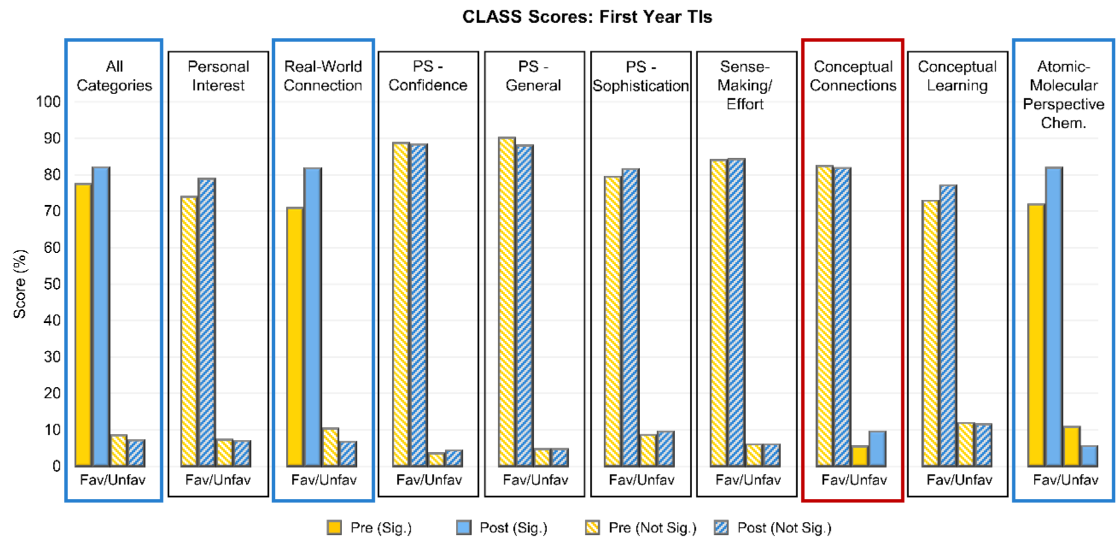


Figure 3.3. Matched CLASS pre-test and post-test results for all first-year TIs. Pre-tests were administered in the Fall semesters, prior to the first week of the program. Post-tests were administered in the Spring semesters during the final week of the program. Blue outlines denote large (p≤0.05) expert shifts, while red outlines denote novice shifts (p≤0.05). Biserial-rank correlations are provided as effect size (N = 48).

Second-year TIs (Table 3.S2) also demonstrated desirable shifts in the combined "All Categories" (r = 0.78) and in the Atomic-Molecular Perspective of Chemistry category (r = 0.67). The full table of scores can be found in the Supporting Information (Tables S1 and S2). Notably, the large undesirable shift in the Conceptual Connections category was not seen in the second-year, with the second-year's post-test score being greater than the first-year's pre-test score. While sample sizes precluded direct comparisons between the groups, the results were encouraging and informative for qualitative purposes.

RQ2: CLASS by Pedagogy Course Enrollment

To understand the role of the Pedagogy Course, PC TIs were analyzed separately. TIs opting to take the PC were given a separate pre- and post-test at the beginning and end of the one-semester course. These TIs saw approximately 50% less facetime with students, and worked primarily in traditional office hours, rather than structured learning sessions like recitations and workshops. In a similar fashion to RQ1, a Kruskal-Wallis test was used to check the assumption that there were no differences between academic years. Again, this assumption was supported and all PC TIs were combined into one group. This group showed a large novice shift in Personal Interest (N=42, $p \leq 0.05$, $r=-1$) and no large expert shifts. We considered that those who enroll in the PC may begin the program with different attitudes compared to those who enroll only in the TI program. However, we did not see any notable differences between pre-test scores of PC and non-PC TIs for any category. All scores for this group can be found in Figure 3.S3.

RQ3, Part I: Relationship of Coursework and CLASS Responses

The third and primary research question asks how the experiences gained by a peer leader are tied to their beliefs about learning and was primarily motivated by discrepancies in the CLASS responses. While the majority of large shifts were in the expert direction, when looking at the individual item responses, there were some statements that had large novice consensus. Because the CLASS does not make specific mention of a particular chemistry course, we questioned whether other coursework could be a confounding factor in TIs' responses. Previous studies have shown differences in scores between General and Organic Chemistry students, which the majority of TIs had taken or were enrolled in at the time.[92] Likewise, we sought to better understand the TIs' responses to the CLASS, as this instrument had not been previously reported on for peer leaders. For these reasons, it was necessary to determine what coursework or experiences motivated TIs' responses to the CLASS.

As previously described, the participants' (Table 3.3) CLASS responses were used to guide the interview protocol. Thirty of the 50 CLASS items were discussed at least once between the thirteen interviews, with some items appearing in as many as ten interviews. In total, there were 79 instances in which the interviewer asked about a specific CLASS item. In 62 of those 79 instances, the TI was able to recall the context that they were considering when responding to that item. Each context response was coded according to course identity or fell under the category of "Chemistry/Science as a Whole." As some TIs discussed more than one context per item, the total "Number of Mentions" is greater than 79. The results are shown in Table 3.4.

Table 3.4. Context of CLASS Items

Context	# of Mentions	# of TIs*	% of All Mentions
Organic Chemistry	34	12	36.6%
TI Program/ Pedagogy Course	25	11	26.9%
General Chemistry	23	13	24.7%
Other Science Course	5	4	5.4%
Chemistry/Science as a Whole	4	3	4.3%
Non-Science Course	2	1	2.1%

*The number of TIs (out of 13) that referenced that context.

Organic Chemistry was identified the most when prompted with a specific CLASS item, followed by the Teaching Internship/Pedagogy Course and General Chemistry. Only General Chemistry was mentioned by all thirteen TIs interviewed, although the first two followed closely behind.

All thirteen TIs cited more than one context during their interview, and some even stated multiple contexts for a single item, noting that it changed over time based on their coursework. This supported our original hypothesis that increased coursework experience could be a confounding factor. One third-year TI, Reema, exemplified how strongly her concurrent coursework influenced her answers. Like most TIs, Reema was enrolled in Organic Chemistry during her first year as a TI. During this time, her response to Item #37 (Box 3.1) had a novice shift. However, the following year, her responses indicated an expert shift had occurred. A snippet of her response can be found in Box 3.1.

Box 3.1. Snippet of Interview with Reema

CLASS Item #37: "In learning chemistry, I usually memorize reactions rather than make sense of the underlying physical concepts."

Interviewer: *When you first came into the [TI] program you disagreed with [Item 37]… that you do NOT usually memorize these reactions instead of making sense, but then you went to agree after one year…when you were still a sophomore.*

Reema: *Yeah*

Interviewer: *When you see this question, what are you thinking of? What were you answering that in the context–*

Reema: [interrupts] *As a sophomore? Orgo!* Where you memorize like a sheet of 50 reactions without thinking about it? Yeah.*

Interviewer: *Okay–*

Reema: *Like when you're in [General Chemistry], you're not working with the same kinds of reactions again and again so you have to understand which one's an acid, which one's a base and then go from there.*

Me: *Right.*

Reema: *Versus Orgo, you do that, but there was so much that at a certain point you just didn't have time to.*

Me: *I understand. And after that year, you consistently selected strongly disagree.*

Reema: [laughs] *Yeah. Once I was done being in Orgo.*

*"Orgo" is the common term for the Organic Chemistry sequence.

In fact, of the ten interviews in which Item 37 was discussed, nine of the TIs' responses cited Organic Chemistry as the reason for their response. Notably, this item is a part of the Conceptual Connections category on the CLASS, which was the only category that saw a novice shift among the first-year TIs.

RQ3, Part II: Origin of Attitudinal Shifts

With strong evidence that individual TIs implicated different contexts while completing the CLASS, it was pertinent to understand the root of the various shifts. To separate the survey data accordingly, the contexts were first mapped to the categories each time a specific CLASS item appeared in the interviews (Figure 3.4). Please note that items from the category "Real World Connections" were not associated with any context during any of the interviews and are thus excluded from the map. Additionally, a small number of items that were discussed during the interviews do not belong to a CLASS category, accounting for slight discrepancies between the totals in Figure 3.4 and the those provided in Table 3.4.

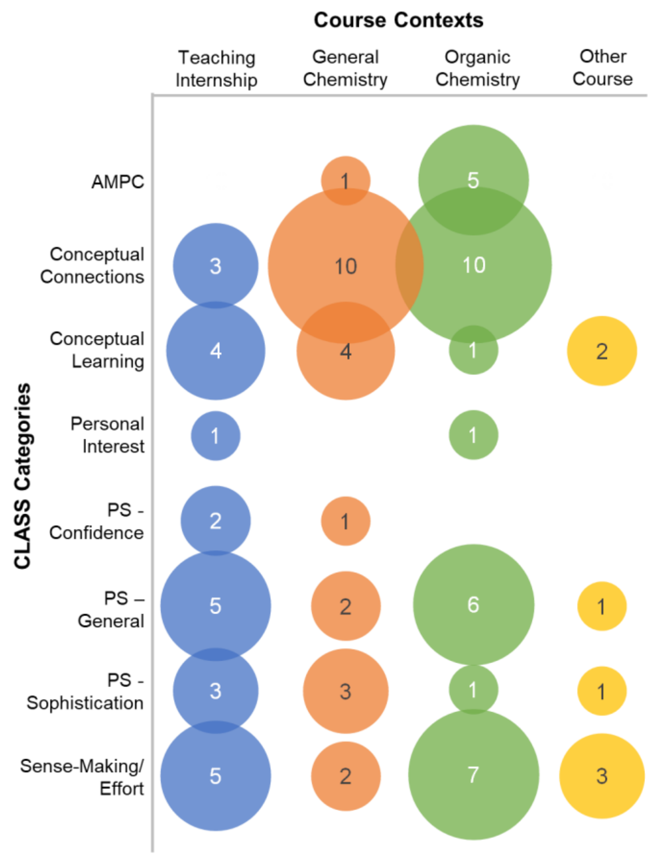


Figure 3.4. This data is based on responses from the interviews with TIs, in which TIs were asked to provide the context that informed their responses on specific CLASS items. CLASS categories are listed on the left, while the courses appear across the top. The bubbles represent the instances in which a CLASS item, belonging to one or more categories, was associated with a specific course. The number of instances is written in the middle of each bubble, and the size of the bubble is commensurate to this number. If an item belonged to two or more categories, it was included as such. Please note that "PS" is abbreviated for "Problem-Solving" and "AMPC" is abbreviated for "Atomic-Molecular Perspective of Chemistry." An alternative representation of this data may be found in the Supporting Information (Fig. S1).

The next step was to map the general direction of the shifts to each course context. As this could only be done for instances in which an interviewee explicitly related a specific context to a shift that they could recall, gathering a large data set was challenging. To maintain consistency with the previous methods, the Agree and Strongly Agree were grouped as "Agree" and Strongly Disagree and Disagree were grouped as "Disagree." Shifts were then only defined as any change between Agree, Neither Agree/Disagree, and Disagree. Thus, shifts from "Agree" to "Strongly Agree," for example, were not counted. In total, 42 instances were identified in which an interviewee explicitly linked a specific context to a shift in their CLASS responses. General Chemistry was not identified as a cause, which was fitting because none of the TIs were enrolled in General Chemistry during their time in the TI program.

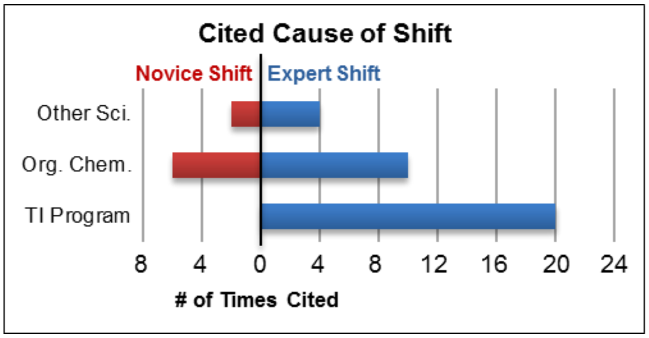


Figure 3.5. Interviewees recalled the cause of any shifts from their CLASS results. The main causes were classified as the TI Program, Organic Chemistry (Org. Chem.), or another science course. General Chemistry and non-science courses were not identified by any of the TIs as a cause of a shift. Red indicates a novice shift, while blue indicates an expert shift.

As shown in Figure 3.5, the majority of shifts were in the expert direction for all three contexts. However, in all instances in which the TI program was cited as the cause, the shifts were favorable. To probe further, the interviewer concluded each interview by asking TIs to consider ways that the TI program may have affected their general attitudes towards learning or chemistry. All thirteen interviewees stated various experiences of positive personal growth resulting directly from the TI/CCE programs, including improved metacognition, confidence, study skills, time management, and resilience. These benefits are elaborated on in the following section.

RQ3, Part III: Other Benefits to Being a Peer Leader

Throughout the interviews, TIs made numerous references to the ways that being a peer leader shaped their beliefs about learning, science, or even about themselves, outside the context of the CLASS. A total of 71 such instances were extracted from these interviews, from all thirteen interviewees. These excerpts were coded by the first researcher (E.L.A.), using an open-coding scheme. The second researcher (D.M.Y.)

independently coded 38/71 of these excerpts using the coding scheme provided, with the option to make changes to the coding scheme if necessary. Eleven categories were developed from these codes, but they were collapsed into nine categories upon discussion with the second researcher. Agreement was initially reached on 35 of the 38 excerpts (92.1%), and upon further discussion, the researchers resolved all discrepancies. Results to this analysis can be found in Table 3.5, and definitions of each category can be found in Table 3.S4 of the Supporting Information.

The most common finding to emerge fell under "Improved Skills and Knowledge," specifically that TIs' Pedagogical Knowledge and Techniques had improved dramatically. While both the TI and CCE programs include a training component, the fact that improved pedagogical content knowledge was a notable benefit that the TIs discussed unprompted was surprising. Further, most TIs (9/13) stated a marked improvement in their problem-solving strategies and/or content knowledge, which is consistent with previous studies on similar populations.[32, 33, 51, 58]

Table 3.5. Other TI Benefits

Category	# of Mentions	% of Mentions	Interview Excerpt
Improved Skills or Knowledge			
Pedagogical Knowledge and Techniques	20	28.2	*My first semester teaching, I'd look at my notes and memorize and be like a robot communicating to the students. But this semester, I don't want to tell them word-for-word a definition. I want to get them to explain it in their own words. Then they're not memorizing things. They're trying to make sense of chemistry.* -Sami
Problem-Solving Strategies	12	16.9	*Honestly I've learned a lot of different methods, not by myself actually, but by a lot of the students. They'll be like 'oh I learned this in high school,' and I just go with it with them…and it helps that way, because now I get a different view of the problem* -George
Learning Through Teaching	7	9.9	*Just growing from the TI program itself, I've learned to apply some of the ideas about learning in my other courses* -Nanjana
Content Knowledge	4	5.6	*When you discuss [chemistry] with students and you're trying to explain it to them, I realized my own knowledge of chemistry had become so much better* -George
View of Chemistry			
Conceptual Connections	8	11.3	*When I was in chemistry, I didn't think all these concepts were connected. But teaching it, and not being in the class but still knowing the answers to questions made me realize, now I got the underlying concepts down. And I don't think a class taught me that. I think the internship taught me that.* -Reema
Personal Interest/Enjoy Chemistry	4	5.6	*[on preparing for teaching] It's a more rewarding experience, instead of prepping for a class. It's more, 'how can I lead them through the process?' And I really enjoy that.* -Kenny
Chemistry in the Real World	3	4.2	*By being a TI I would say that I've realized chemistry is everywhere in life. You don't think about it all the time, but then you'll see something and you'll be like 'oh I know how that happens!'* -Manasi
Interpersonal/Intrapersonal Growth			
Confidence/ Persistence	4	5.6	*I think that [TI-ing] made me more confident in what I think I know about Gen Chem, or chemistry in general.* -Marla
Empathy/ Appreciation	9	12.7	*I work in a hospital and I'm better on the patient care aspect now. Like when explaining their medication or their schedule for the day. I'm more, I guess, empathetic. That reminds me of how I used to teach people versus now.* -Emma

Stepping away from the chemistry, another often-discussed benefit was labeled Empathy/Appreciation, whereby TIs acknowledged developing a better understanding of students' struggles or a newfound appreciation of their own professors. Indeed, at the end of the interview, when asked how the TI program changed their views of chemistry, one TI described how their students gave them a new understanding of their own past experiences:

> Where I went to school, originally, that area is kind of an underserved area. And then moving, having the majority of my high school in [a wealthier town], that really changed me. But even then, when I thought about chemistry, I overlooked that, because for me, it was generally like if you work for it, you get it. But it's not necessarily like that because if some people are coming from an area where they haven't been paid attention to their entire life, there's just some things you can't change, so I feel like I'm noticing things like that more now. (Nanjana)

When the topic of empathy arose, four TIs referenced the lesson on equity, inclusion, and diversity from their weekly staff meetings, suggesting that these topics left a lasting impact.

RQ4. CLASS Utility for Peer Leaders

The final research question asks whether or not the CLASS is a suitable, valid instrument for assessing the learning beliefs of peer leaders. There were instances in which a TI would contradict their written answers in an interview or state that they did not know why they answered the way they did. When this occurred, the item and response were discarded from the aforementioned qualitative analysis. The most commonly-stated cause for these discrepancies was a misunderstanding of the question. Nine of the thirteen TIs cited this at least once during their interview, with none of them stating it more than twice. On the other hand, it is possible that meanings changed over time:

> Initially I agreed [that doing lots of problems was helpful], but actually, from my perspective now, I didn't realize how many problems other people did. I genuinely had no idea. I did maybe two practice exams max and I thought that was a lot. Until I started working with students. (Ronit)

Other potential sources for a discrepancy could be survey fatigue (taking the CLASS multiple times over the years) or simple forgetfulness. The "lazy data" removed from statistical analysis was not included in the interviews.

Ultimately, mixed results on the survey indicated that the survey data alone was not satisfactory to determine the effect that the TI program had on these participants' attitudes. Interview data suggested that TIs were implicating multiple different contexts when responding to the survey items, and that different contexts were associated with different attitudes:

> I think I did most of [the survey] in the mindset of Gen Chem. But the questions about how you feel about the subject of chemistry, I was thinking of being a TI. So it depends on the question. But I wouldn't say as an Orgo student. My thoughts on Orgo are a little different. (Niven)

Interestingly, five TIs explicitly acknowledged approaching their own current coursework differently from how they encourage their students to approach it. For example:

> When the student comes in, I have to encourage them, even though it's not what I necessarily always do, I tell them you can't just sit there and memorize this, that you have to understand why it works. I try to explain that, even though I don't always do that myself. (Zara)

> The biggest thing was that it's important for them to do the process rather than just give them answers, to have them work through it… but then sometimes I go to office hours and I might just really want the answer [laughing]. (Kenny)

This lends support to the idea that for this particular population that has experienced multiple chemistry courses, the CLASS is not simply assessing "chemistry" as a particular course, but perhaps a combination of courses or prior experiences, or even as a discipline in general, as one TI stated "I was just thinking of my experiences in general, like with my entire chemistry career." (Emma)

Discussion: Context Matters

From the data presented here, it appears that TIs do experience positive growth in their attitudes towards learning chemistry as a result of their time in the program. This is consistent with previous work that has shown that different instructional practices can impact students' scientific beliefs.[75, 77, 105] All TIs participated in some form of weekly pedagogy training that focused on the nature of learning and the scientific process, and received continuous feedback on how to apply their training to actual teaching experiences. Likewise, these findings add to the growing body of knowledge about the benefits that peer leaders have been shown to gain. [20, 30, 32-35, 45, 51, 58]

TIs who opt to take the Pedagogy Course were not found to have large changes in learning attitudes during their first semester. Further, there was no evidence to suggest that these PC and non-PC TIs begin their respective programs with different attitudes. It is possible that one semester, approximately 14 weeks, is not enough time to capture meaningful data, keeping in mind that the PC TIs only gained half the teaching experience as the non-PC TIs. Alternatively, it could be that the PC TIs' training was simply different in nature and the results of which could not be properly evaluated by the CLASS. Previous studies have shown that a formal pedagogy course did offer unique benefits, suggesting that this latter possibility may hold some truth.[32, 35, 106, 107] For example, in their study on a population that included TIs, Blackwell et al. identify the PC as "the most critical component of [peer leaders'] training and professional development," citing one peer leader who stated that the course was influential in learning about their own learning.[32] Further, our own course evaluations of the PC have been overwhelmingly positive. Perhaps most encouragingly, the small number of TIs who took the PC after one or more semesters of being a TI noted benefits gained specifically due to the PC. More rigorous work on a larger sample would be needed to fully capture any differences between PC and non-PC TIs.

Concerning our primary research question, RQ3, interview data ultimately aided in our understanding of how the TI program, through teaching or training, affects TIs' attitudes towards learning chemistry. Each mention of peer leadership corresponded to expert responses and/or shifts in attitudes. Aside from specific items from the survey, TI responses about their experience in the program suggested that they gained valuable skills and a matured perspective on their own education and on chemistry and learning in general.

All thirteen interviewees stated that their responses were context-dependent. Interestingly, one interviewee stated that when they were conflicted about their level of agreement for an item because they were considering two different contexts, their beliefs developed from the TI program took higher precedence and affected their survey response accordingly. While it is not possible to generalize this statement to the population, there were multiple instances in which TIs admitted to not always practicing what they preached. This sentiment was similar to that found by Adams et al.,[93] in which physics students taking the CLASS were found to hold personal beliefs that differed from beliefs they perceived an expert would hold.

Challenges and Limitations

One challenge for conducting this study was that participants were asked to discuss coursework and the CCE/TI programs with the programs' coordinator. This introduces the possibility that certain beliefs or experiences were not disclosed by the TIs if they felt that those beliefs and experiences were not positive or aligned with the programs' pedagogical philosophy. To minimize these concerns, interviews were conducted at the end of the Spring 2018 semester, after TIs were presumably more at-ease in the program. Continuous efforts were made throughout the year to invite constructive feedback from TIs, encourage honest self-reflection, and promote a safe environment for discussion. For the interview, participants were told that the purpose was to understand their coursework experiences in general. At no point during the CLASS portion of the interview did the interviewer explicitly name the TI program unless it was brought up by the interviewee, so as to avoid any "prompting." The final question asking them to discuss their experiences and attitudes as a TI was purposefully reserved for the end.

One limitation for this study is the modest sample size. Typically, the CLASS has been administered in large courses, such as General Physics or General Chemistry, where the sample size can extend into the thousands. In this case, the sample size reduced the statistical power and impeded the ability to draw many meaningful conclusions from the quantitative data alone. Secondly, this sample was relatively homogenous in terms of academics. The TIs were selected from the top of their General Chemistry class, enrolled in similar coursework, and the overwhelming majority held interest in healthcare careers. Even in cases of novice shifts, their CLASS scores were still high compared to a typical General Chemistry population,[92] introducing the possibility of "maxing out" the instrument. Still, the qualitative data provided meaning to some of the results where the statistics could not.

Implications for Instruction and Research

The calls to promote classroom equity and to foster so-called "21st Century Skills" such as scientific thinking have shaped recent educational practices.[16, 108-113]z The paradigm of learning through teaching is well-supported, and this research suggests that teaching, and learning how to teach, may impact one's beliefs about learning science, and thus their scientific thinking. Encouraging this as a practice either through formal programs like the Teaching Internship or simply as a classroom exercise may foster this type of development in our STEM students.

Interview evidence suggested that at least some TIs simultaneously hold opposing expert and novice beliefs about learning and that they may act on those beliefs differently given a specific context. If we suppose that a TI's conflicting beliefs are a direct result of their diverse experiences, it would be of interest to examine what factors of a course or program determine precedence in their selection. For practitioners, this fact also emphasizes the importance of incorporating practices that foster positive/expert beliefs about science and learning throughout multiple courses, rather than isolating these practices as their own entity.

Within our own population, these findings have prompted modifications to the PC and TI staff meetings. For example, TIs are given in-class activities which provide opportunities for them to explicitly apply their pedagogical knowledge to their own coursework, such as Organic Chemistry, in addition to their General Chemistry duties. By encouraging a broader application of these skills and concepts, TIs may not only improve their General Chemistry pedagogical content knowledge, but perhaps also develop more expert-like attitudes about learning and chemistry across the field. In a similar manner, small changes have since been made to discuss the importance of empathy when working with students. Topics of equity, inclusion, and diversity have been incorporated within other topics throughout the semester for both the PC and the TI staff meetings.

To our knowledge, detailed CLASS data has not been reported on previously for a peer leader population, although Otero et al. do note positive overall attitude changes in Physics LAs.[114] The instrument served as a valuable starting point for our investigation on peer instructors' learning attitudes about chemistry. Interviews were then necessary as a means of clarification for conflicting or unexpected responses, as well as to assess the validity of its use in our population. In the future, a modified version of the survey may help to more easily pinpoint attitude changes specific to a peer leader's role. Such an instrument could investigate similar beliefs about learning chemistry, while prompting participants to consider their training or experiences in this role. This data may inform the pedagogical practices and/or overall structure of the program to target peer leaders' learning beliefs. Alternatively, this data could be compared with their attitudes stemming from other coursework, expanding upon the work discussed in this paper. If similar results are found, such that peer leaders do compartmentalize or rank beliefs based on a specific context, it may be worth investigating why this divergence occurs and provide an argument for incorporating explicit pedagogical content knowledge within the early general STEM course curricula.

Acknowledgments

The authors would like to express our sincerest gratitude for the on-going advice and assistance of Dr. Mary Emenike and Dr. Marc Muñiz. We would also like to thank the Rutgers Department of Chemistry and Chemical Biology for their support in this project, as well as the Teaching Interns for their consistent cooperation, and the Head Teaching Interns for their vital work and feedback in helping to run the TI program. This work would not have been possible without the support, infrastructure, and collaboration of the Cyberlearning Innovation and Research Center, funded by the School of Arts and Sciences at Rutgers, New Brunswick. Lastly, we would like to acknowledge funding provided by the National Institutes of Health [GM62248].

Supporting Information for Chapter 3

I. The Teaching Internship

The General Chemistry TI program was piloted in the Spring of 2014 and later fully implemented in its current form in the Fall of 2015. The three components of the program consist of weekly staff meetings, learning sessions, and written reflections. Interactive weekly staff meetings are conducted by the program coordinator (E.L.A.) and primarily consist of hands-on best practices training, with some time allotted for content preparation or to discuss other issues that arise as needed. The learning sessions conducted by these TIs vary from small-group office hours to collaborative workshops and our Active Learning Recitations. Teaching Interns are responsible for these sessions for the entire semester and hold approximately two sessions per week for each credit of the TI program (up to 2 credits). TIs submit a weekly, semi-guided reflection post to their blog on the course management website, evaluating their experiences and takeaways from the staff meeting and their learning sessions. TIs are also required to comment on at least one TI's post each week.

Students who perform well in the General Chemistry courses are invited to apply to the Teaching Internship program midway through their second semester of the General Chemistry course sequence. Students who received AP/transfer credits for the first semester of General Chemistry are included in this invitation. Students who received AP/transfer credits for both semesters of General Chemistry do not receive an invitation as they are not enrolled in the course, but they may be considered on a case-by-case basis. After completing a short online application, invitees participate in a face-to-face group interview where they are observed by both the coordinator and 2-4 current TIs. Approximately one-third of the interviewees are selected. TIs may continue in the program for as many semesters as they choose, at the discretion of the coordinator, without needing to re-apply. The split between new and returning TIs each fall semester is approximately 50/50, excluding the pilot semester (Fall of 2015).

II. The Certificate in Chemistry Education (CCE)

The CCE application process is identical to that of the TI program and both sets of applicants are interviewed together. The first requirement is the Pedagogy Course, a formal, 3-credit course created and taught by the author (E.L.A), which is modeled after a similar course reserved for Learning Assistants. The course is conducted in a flipped-classroom style in which students must read the assigned literature ahead of time. In class, students work in groups on an activity that applies this new knowledge to their learning sessions with General Chemistry students. Unlike the weekly staff meetings for the non-PC TIs, the Pedagogy Couse has weekly homework, multiple papers, and an exam. This course covers educational theories and concepts, such as constructivism, collaborate learning, mental models, and metacognition. PC TIs hold learning sessions with General Chemistry students for one hour per week, and typically in the form of an office hour. Like the other TIs, they also must complete weekly written reflections.

After completing the Pedagogy Course, students in the CCE program sign up for the TI program. Although this credit requirement can be completed in one semester, virtually all TIs opt to spread the credits over two semesters, with most taking additional credits of the TI program. Thus, the CCE program includes the TI program, but not all TIs are a part of the CCE program. The final requirement includes being the solo instructor for the General Chemistry labs, which is reserved specifically for junior and senior-level students.

III. Statistical Analysis

The rank biserial correlation r is equal to the sum of the signed ranks, W, divided by the total rank sum, S, i.e.:

$$r = \frac{W}{S} \tag{1}$$

Kerby[104] provides an alternate way to calculate the rank-biserial correlation for the Wilcoxon signed-rank test, called the Simple Difference Formula, by using the difference between the proportion of positive rank sums and the negative rank sums:

$$r = f - u \tag{2}$$

Here, f refers to the proportion of favorable ranks and u refers to the proportion of unfavorable ranks. The two methods are mathematically equivalent. The correlation r ranges from -1 to 1, where 0 indicates no relationship and the sign of the correlation provides insight as to whether or not the result matches the hypothesis.

IV. CLASS Categories

The CLASS consists of nine categories. Three categories target students' beliefs on problem-solving, including their confidence, sophistication, and general skills. The "Conceptual Learning" and "Conceptual Connections" categories provide statements about how the topics in chemistry connect and whether or not students prioritize memorization over understanding. Similarly, "Sense-Making/Effort" explores how (if at all) students apply chemistry concepts to rationalize their answers or understanding. "Personal Interest" and "Real-World Connection" focus on students' personal beliefs about chemistry and its application or utility outside of the classroom. The final category, "Atomic-Molecular Perspective of Chemistry" includes statements about how students use the atomic or molecular representations to understand chemical phenomena or to solve problems. This category is unique to the CLASS-Chem, with the other eight originating from the CLASS-Physics instrument. With the exception of items in the last category, there is at least some overlap in the other eight, meaning individual survey items simultaneously belong to two or more categories. Figure 3.2 of the main manuscript shows the overlap of items in each category using a Venn diagram, with a larger overlap signifying a greater number of items belonging to two (or more) categories.

V. CLASS "Lazy Data" Response Filtering

The CLASS uses statements given in both the positive and negative, meaning some garnered expert agreement while others converged on expert disagreement. Thus, students cannot earn a "high score" by checking the same answer for each item. "Lazy data," in which participants seemed to be selecting answers at random, were removed from our analysis via two checkpoints. Item 31 asks students to select "Agree" for that statement, and failure to do so would result in elimination. This did not occur throughout any of the TIs' surveys. The second step flagged participants whose survey had 40% or more of the same response. In this case, the entire survey would be individually checked and retained or discarded on a case-by-case basis. This occurred two times, with one of those sets discarded after discovering that the participant selected "Agree" for the last 35 items. The other survey was retained after finding no unusual responses.

Additional Data Tables

Table 3.S1. CLASS Scores: First Year Teaching Interns (N=48)

Category		Pre-test Average	Post-test Average	Shift*	Effect-Size, r
All categories	Favorable	77.5	82.0	4.51*	0.42
	Unfavorable	8.6	7.2	-1.39	
Personal Interest	Favorable	74.0	78.8	4.86	
	Unfavorable	7.3	6.9	-0.35	
Real World Connection	Favorable	70.8	81.8	10.94*	0.58
	Unfavorable	10.4	6.8	-3.65	
Problem-Solving: General	Favorable	88.8	88.3	-0.42	
	Unfavorable	3.5	4.4	0.83	
Problem-Solving: Confidence	Favorable	90.1	88.0	-2.08	
	Unfavorable	4.7	4.7	0.00	
Problem-Solving: Sophistication	Favorable	79.5	81.5	2.08	
	Unfavorable	8.6	9.5	0.89	
Sense Making/Effort	Favorable	84.0	84.3	0.23	
	Unfavorable	6.0	6.0	0.00	
Conceptual connections	Favorable	82.4	81.8	-0.60	
	Unfavorable	5.4	9.5	4.17*	0.67
Conceptual learning	Favorable	72.9	77.1	4.17	
	Unfavorable	11.9	11.6	-0.30	
Atomic-Molecular Perspective of Chemistry	Favorable	71.9	81.9	10.07*	0.54
	Unfavorable	10.8	5.6	-5.21*	0.56

*indicates significance at $p \leq 0.05$

Table 3.S2. CLASS Scores: Second Year Teaching Interns (N=19)

Category		Pre-test Average	Post-test Average	Shift*	Effect-Size, r
All categories	Favorable	82.9	87.0	4.1*	0.78
	Unfavorable	5.0	4.7	-0.3	
Personal Interest	Favorable	80.7	85.1	4.4	
	Unfavorable	5.3	3.5	-1.8	
Real World Connection	Favorable	80.3	84.2	3.9	
	Unfavorable	7.9	5.3	-2.6	
Problem-Solving: General	Favorable	91.1	92.6	1.6	
	Unfavorable	2.1	2.6	0.5	
Problem-Solving: Confidence	Favorable	93.4	96.1	2.6	
	Unfavorable	0.0	1.3	1.3	
Problem-Solving: Sophistication	Favorable	85.7	90.2	4.5	
	Unfavorable	3.8	3.8	0.0	
Sense Making/Effort	Favorable	83.6	88.9	5.3	
	Unfavorable	4.1	4.7	0.6	
Conceptual connections	Favorable	86.5	89.5	3.0	
	Unfavorable	4.5	3.8	-0.8	
Conceptual learning	Favorable	82.7	86.5	3.8	
	Unfavorable	6.0	6.8	0.8	
Atomic-Molecular Perspective of Chemistry	Favorable	78.9	86.8	7.9*	0.67
	Unfavorable	5.3	3.5	-1.8	

*indicates significance at $p \leq 0.05$

Table 3.S3 CLASS Scores Pedagogy Course Teaching Interns (N=42)

Category		Pre-test Average	Post-test Average	Shift*	Effect-Size, r
All categories	Favorable	84.9	85.1	0.3	
	Unfavorable	4.8	6.5	1.7	
Personal Interest	Favorable	81.7	83.7	2.0	
	Unfavorable	2.0	6.3	4.4*	-1
Real World Connection	Favorable	82.1	86.3	4.2	
	Unfavorable	6.0	5.4	-0.6	
Problem-Solving: General	Favorable	91.7	91.4	-0.2	
	Unfavorable	1.9	2.6	0.7	
Problem-Solving: Confidence	Favorable	93.5	90.5	-3.0	
	Unfavorable	0.6	3.6	3.0	
Problem-Solving: Sophistication	Favorable	86.7	84.4	-2.4	
	Unfavorable	4.1	7.1	3.1	
Sense Making/Effort	Favorable	89.4	89.4	0.0	
	Unfavorable	5.3	4.0	-1.3	
Conceptual connections	Favorable	88.4	88.4	0.0	
	Unfavorable	3.4	4.1	0.7	
Conceptual learning	Favorable	83.3	79.6	-3.7	
	Unfavorable	6.8	10.2	3.4	
Atomic-Molecular Perspective of Chemistry	Favorable	79.8	81.7	2.0	
	Unfavorable	6.0	8.7	2.8	

*indicates significance at $p \leq 0.05$

Table 3.S4. Definitions of Other TI Benefits

Category	# of Mentions	% of Mentions	Definition
Improved Skills or Knowledge			
Pedagogical Knowledge and Techniques	20	28.2	From teaching perspective: Use of pedagogical techniques, such as cooperative learning, facilitation of knowledge (versus teaching "at" students), etc. in the context of General Chemistry; Endorsement of teaching practices based on meaningful learning, metacognition, constructivism, etc.
Problem-Solving Strategies	12	16.9	Acquirement of new methods or general, productive approaches for solving chemistry problems, including the judgment of the feasibility of an answer; Improved efficiency in solving chemistry problems
Learning Through Teaching	7	9.9	From student perspective: General knowledge or skills about learning gained through the TI program and applied to own coursework (e.g. improved study skills)
Chemistry Content Knowledge	4	5.6	Improvement in own knowledge or understanding of concepts in General Chemistry
View of Chemistry			
Conceptual Connections	8	11.3	Recognition of or improvement in ability to form connections between concepts within chemistry or between other science disciplines; Belief that all topics in chemistry are connected by a finite set of underlying concepts (versus the view of chemistry as discrete, independent topics)
Personal Interest/Enjoy Chemistry	4	5.6	Increased fascination with chemistry or intrinsic motivation to learn more about chemistry, beyond what is necessarily required for a course; General feeling of satisfaction when learning chemistry
Chemistry in the Real World	3	4.2	Recognition of chemistry-related phenomena in everyday life, outside of the classroom; Use of practical examples to teach or understand chemistry
Interpersonal/Intrapersonal Growth			
Confidence/ Persistence	4	5.6	Increased belief in own abilities to succeed academically and/or to be able to tackle new challenges
Empathy/ Appreciation	9	12.7	Development of a stronger sense of compassion for those that are struggling, including students in the class and/or for others in general; Acknowledgement of the effort professors put into teaching

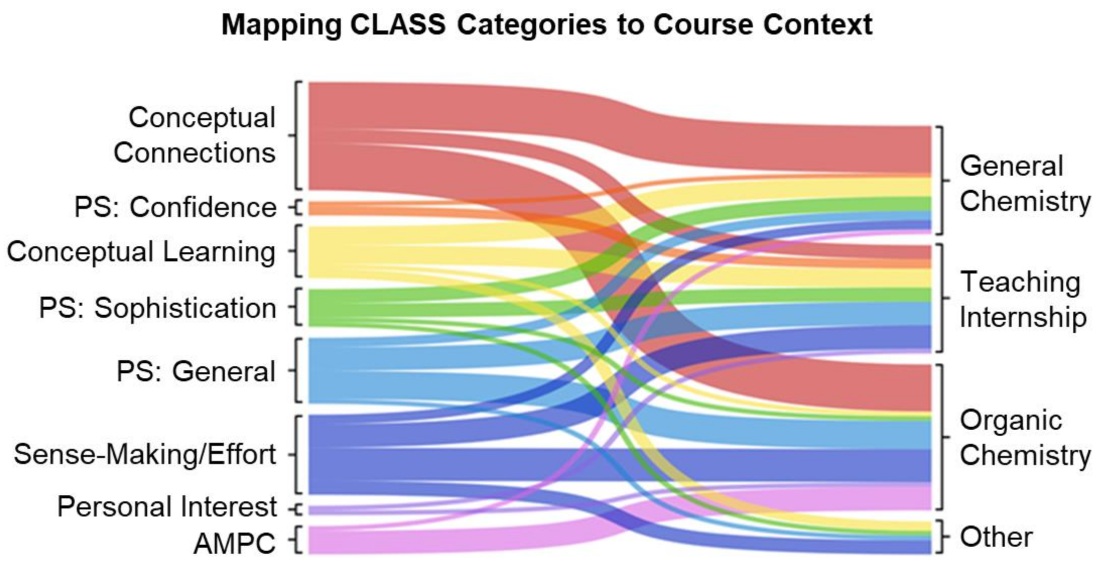


Figure 3.S1. An alternative representation for Figure 3.4. Each CLASS category (left) is mapped to a specific context (right), based on the responses from the interviews. If an item belonged to two or more categories, it was included as such. The thicker the line, the more items from that category were mapped to a given context listed on the right. "PS" is an abbreviation for "Problem-Solving;" "AMPC" is an abbreviation for "Atomic-Molecular Perspective of Chemistry."

Chapter 4 | Give and Take: Narrowing the Gap Between Theory and Practice of Peer Instructors Over Time

Abstract

Peer instruction is used as a means of facilitating knowledge-building among students of similar age and experience levels. Peer instructors often differ from other teaching roles in terms of authority, training, and teaching experience, all of which may influence how they are perceived by their students. If the implementation of peer instruction continues to expand in higher education, then the interactions between peer instructors and their students remain a critical component of student learning and warrant further investigation as a means to improve the efficacy of such programs. In this work, the Teaching Internship program provides supplemental learning sessions for students in the General Chemistry course sequence. The Teaching Interns (or TIs) are the peer instructors that have been selected from a pool of former successful General Chemistry students. All TIs undergo weekly training and reflection activities to help articulate, develop, and practice their teaching approaches. In this multi-case study, a qualitative approach is used to investigate the verbal behaviors of the TIs and the extent to which those behaviors match their beliefs about teaching. Discourse analysis is used to characterize the interactions between TIs and students as monologic, dialogic, or noninteractive. The TIs' weekly reflections are used to provide insight into their beliefs about teaching as well as their perception of their own teaching sessions. Two TIs are each observed in their office hours over the span of one semester, one year, or two years. The results provided here suggest that even at the start of the program, TIs hold some productive beliefs about teaching, such as the importance of understanding versus memorizing and the value in co-constructing knowledge with the student. However, these beliefs were not necessarily aligned with their practices, as demonstrated by TIs' heavy use of monologic discourse, shallow explanations of knowledge, and noninteractive behaviors. After one semester of teaching and pedagogy training, the TIs showed remarkable improvements in their use of student-centered

discourse and abilities to convey or elicit deeper knowledge amongst their students. These behaviors continue to progress as the TIs gain further experience. Additionally, the TIs improved in their abilities to self-monitor their own teaching behaviors, closing the gap between their practices and espoused beliefs about teaching, and appear to tune their focus towards bettering student learning rather than simply managing their sessions.

Introduction

As institutions of higher education seek to make their classrooms more conducive to active learning, peer instruction has been one type of reform to facilitate this process. Within peer instruction, undergraduate student learning is facilitated by other undergraduates, usually of whom have demonstrated prior success in the same course, and often have had pedagogical training in instruction. There is an extensive literature on the benefits of peer instruction for students on the receiving end,[16, 19, 22] as well as for the peer instructors themselves.[1, 20, 32, 33] Aside from assessing the outcomes, researchers have considered the interactions that occur during these peer instruction sessions in order to better understand the impact of these programs on the student learning processes. For example, Kulatunga and Lewis[115] examined the extent to which peer instructors are able to implement methods of argumentation in their Peer-Led Process Oriented Guided Inquiry Learning (POGIL) sessions. The researchers linked students' argumentation patterns to the specific verbal behaviors of the peer instructors. In another study, Smith and colleagues[116] investigated the differences between peer instructors' behaviors within a traditional Peer-Led Team Learning (PLTL) settings versus its cyber counterpart (cPLTL). However, it remains unclear as to how the modes of interaction of peer instructors' change over time, how their training is tied to those changes, and whether or not the peer instructors are cognizant of those changes.

The participants in the current study are the Teaching Interns, or TIs, who serve as the peer instructors in the General Chemistry course sequence at Rutgers University.[1, 4] Specifically, this research investigates the ideas that these peer instructors hold about their role and about teaching in general, as well as how those beliefs align with their actual teaching practices. This work seeks to understand how the theory-practice gap evolves over time as the TIs gain pedagogical knowledge and experience. Such questions have been examined within the context of teacher training and tutor learning; however, peer instructors are unique in that they are not typically seen as figures of authority as teachers are,[13, 50] and in most cases, they receive training in how to conduct their learning sessions, unlike the many tutors.[117] In this way peer instructors afford an opportunity to examine an important middle ground that also represents a key element of teaching and learning infrastructure at many universities, including Rutgers.

A multi-case study approach was taken to follow a total of six TIs over varying lengths of time to monitor the changes that occur during their learning sessions with students. Two TIs each were observed over one semester, one year, and two years. Analysis of these observations included the ways in which they communicated information to their students, as well as the content of that information. Weekly written reflections by the TIs were used in conjunction with these observations to gain insight as to how they evaluated their learning sessions and viewed their progress. This work begins with a brief background on peer instruction and a thorough look at how discourse analysis been used to characterize classroom dynamics in the literature. Practical theory was selected as a framework to guide this research and stems from the two research questions that were developed. A description of the setting provides the context for this study, while the subsequent methods section details the exact procedures of data collection and analysis. Because this study is structured as a case study, the results and discussion section are combined in order to maintain the flow from case to case. The paper concludes by highlighting the major findings and how they are tied to some key implications for practice and future research exploration in this domain.

Background

Peer Instruction and Social Constructivism

The implementation of peer instruction, sometimes referred to as near peer instruction,[26] has grown tremendously since the early days of Supplemental Instruction (SI).[41] Countless other models have since been implemented and reported on in the literature, spanning a variety of disciplines (chemistry,[1, 106] nursing,[12] computer science,[45] sociology,[18] etc.) and program structures. There is no singular peer instruction program model, and so they often vary widely in their structure and training mechanism. Still, one guiding principle for many of these programs is social constructivism and the practice of facilitating knowledge through scaffolding.[118-120] The premise of social constructivism stems from the work of psychologist Lev Vygotsky and refers to the construction of knowledge by an individual achieved through social interactions.[5, 121, 122] As Murphey describes near peers as those close in age and social level,[26] it is fitting that a constructivist framework underlies these peer instruction programs, as students are able to co-construct knowledge with those of a similar level and background. However, Velasco and Stains discuss,[123] the frequency of training is likely a contributing factor as to how well these peer instructors are able to maintain a constructivist environment.

The present study looks at undergraduate students enrolled in the Teaching Internship (TI) program.[1, 4] This program is a peer instruction model in which former, successful General Chemistry students assist current General Chemistry students through supplemental instructional sessions. The TIs receive weekly pedagogy and best practices training, which is framed in the context of social constructivism. TIs are taught to facilitate students' knowledge, via effective questioning and scaffolding, rather than through didactic lectures. The goal of this research is to evaluate the ability of TIs to conduct their learning sessions in this manner by examining the dialogue that arises with their students. A detailed description of their roles, training, and responsibilities can be found in a subsequent section, under Setting.

Discourse Analysis

Discourse analysis is a collection of methods used to investigate and ultimately characterize verbal, written, and non-verbal forms of communication within a defined setting.[124] In the education literature, such analysis is typically used to examine interactions between two or more students in a classroom or between the instructor and the student(s). For example, Shultz and Li[125] used discourse analysis to analyze the group dialogue of students enrolled in a problem-based learning laboratory course. The researchers identified the ways that students use external resources to solve a problem in the context of information literacy. In a study by Dohrn and Dohn,[126] the researchers were investigating the way(s) in which different types of questions influence classroom dynamics in a high school chemistry class. Specifically, discourse analysis was used to classify the questions posed and analyze the subsequent student responses. As evident in both of these studies, discourse analysis often makes use of an analytical framework in order to answer the research questions at hand.

Identifying the Dimensions of Discourse

Within discourse analysis, there are variety of different lenses used to interpret social interactions in an educational setting. Observational data collected from the present study is analyzed according to three distinct dimensions to characterize the information being communicated between TIs and students: (1) direction of information, (2) type of information, and (3) depth of information

First, the direction of information refers to the person (or people) who are contributing the substance within an interaction. In the education literature, this direction is often used to characterize the verbal exchanges between a teacher and their student(s). One common dichotomy is the classification of monologic versus dialogic discourse. The term "monologic" generally describes discourse that is transmitted unidirectionally, e.g. from the teacher to the student.[127] Conversely, dialogic discourse invites equal participation from all parties, usually in the context of co-constructing learning.[127] Similar schemes have been used previously, such as interactive versus noninteractive discourse.[128] O'Connor and Michaels made a point to clarify the differences between structural and ideological monologic and dialogic discourse, denoting the ideological forms as Monologic and Dialogic, versus the lower-case structural forms.[129] In their work, they explain how episodes of dialogue can take on mixed ideological and structural forms. For example, a teacher asking a student questions while the student responds is dialogic in structure (the dialogue is bidirectional) but Monologic in ideology, as the teacher is recognized as the authority and holder of knowledge. Peer instructors are not intended to be authority figures or content knowledge experts. In their interactions with students, such age and status differences are negligible or even ambiguous. Thus, the present study makes use of the structural form of monologic and dialogic discourse.

In addition to how information was directed, researchers have also investigated the types of information that can arise in a classroom. For example, Dohrn and Dohn[126] characterize the various questions posed by chemistry teacher according to content (e.g. academic) and function (e.g. clarification). In the context of a tutoring session, Velasco and Stains[123] classify the type of information exchanged as "knowledge" or "common ground." This classification system is aligned with the writings of Wells and Arauz,[127] who argue that in order for dialogue to be effective, both participants must "make a persistent attempt to understand each other's perspectives." Within the context of a TI-led chemistry office hour, this form of negotiated understanding is distinct from the exchange of factual knowledge and formed the two categories within this dimension.

A third dimension pertinent to this study further describes the quality or depth of knowledge which is being communicated. In the aforementioned study, Velasco and Stains[123] further divided their knowledge category into knowledge-telling behaviors and knowledge-building behaviors; however, common ground codes were not differentiated in this way. Similarly, Graesser and Person[130] evaluated the quality of questions posed by teachers/tutors based on the length of an answer and the level of reasoning required by the student. Both of these approaches were adapted in this study to draw distinct boundaries between "deep" and "shallow" knowledge questions and explanations in order to better illustrate the changes in TIs' verbal behaviors that occur over time.

Framework

Practical Theory

Practical theory refers to the collection of ideas, beliefs, knowledge, and experiences that shape the actual practices of an instructor.[131] This is in contrast to the teaching practices that an instructor may verbally advocate for, which may or may not be aligned with their practical theory. Argyris and Schon use the term congruence to describe the alignment of one's "theory-in-practice" (what they actual do) with their "espoused theory" (what they claim to do).[132] Using this framework, Jaap Buitink[131] looks at the way student teachers develop and modify their practical theories while immersed in a school-based teaching program. The researcher defines a well-developed practical theory as one that takes into consideration the actual learning process of the students, rather than just their own perspectives, performance, or classroom management concerns. Buitink refers to this mediocre practical theory as a teacher simply looking for "survival." Velasco and Stains[123] used this same framework to investigate the relationship between tutor behaviors and perceptions of teaching. One difference between these two studies is that student teachers had undergone formal training to be a teacher, whereas the tutors had not.

Peer instructors offer a unique opportunity to explore the concept of practical theory, as they exist in the same realm as students, having remarkable similar prior experiences and perhaps even day-to-day experiences as the students they teach. However, in the case of TIs, their pedagogical training differentiates them from most tutors. Likewise, their training is continuous and concurrent to their teaching duties, which evidence suggests is necessary for novice instructors to be able to successfully apply theory to practice. [107, 133] This study uses observations to characterize TIs' practices, coupled with their written reflections to gauge their beliefs about their teaching methods. An in-depth look at a subset of TIs over varying intervals of time in the TI program will help to elucidate how the TIs' practical theories shift, if at all, and if there is congruence between their practice and espoused theory.

Research Questions

The guiding questions behind this investigation seek to paint an overall picture of what a typical office hour looks like for a Teaching Intern, and how that relates to their own perception of their teaching practices. The three research questions can be state as follows:

1. To what extent do peer instructors change in their use of unidirectional and bidirectional verbal behaviors as time goes on?
2. To what extent does the content of the interactions between peer instructors and their students change?
3. Does a peer instructor's beliefs about teaching differ from their actual teaching behaviors?

Setting

Location

Rutgers University is public research-intensive university, serving as New Jersey's flagship university. Each year, Rutgers hosts approximately 70,000 students, including 20,000 graduate students. The TIs in this study assist students in the General Chemistry course, which enrolls approximately 2,000 students per semester. The courses are taught by four or five different instructors per semester, but all students complete common exams, quizzes, and online homework. In addition to lectures, all students attend an online, weekly recitation. Each week, the TIs hold numerous supplemental help sessions for students to attend on an as-needed basis.

The Teaching Interns

The university offers undergraduates numerous certificates to earn alongside their degree. One certificate program founded in 2015 is titled the Certificate in Chemistry Education (CCE) program.[3] This nine-credit program includes a Pedagogy Course and experience in teaching for both the General Chemistry courses and the laboratory. The list of requirements for the CCE program can be found in Table 4.1. Alternatively, students can become involved in teaching by enrolling in any of the three CCE components separately, without earning the certificate. The majority of Teaching Interns each semester are not a part of the CCE program.[4] Students are invited to apply and interview for either program based on their success in General Chemistry. While TIs are expected to demonstrate their knowledge of chemistry, an "A" in the course is not required. Group interviews are used to give prospective TIs the opportunity to demonstrate their ability to communicate chemistry with their peers and work collaboratively on the questions and activities presented in the interview. Approximately 15 students enroll in the Pedagogy Course per semester, while the average enrollment of the Teaching Internship ranges from 40-50. Of those in the TI program in a given semester, nearly half are second- or third-year TIs.

Table 4.1. Certificate in Chemistry Education (CCE) Coursework and Requirements*

Course	Length (Semesters)	Credits per Semester	Weekly Requirements
Introduction to Chemistry Education (Pedagogy Course)	1	3	Flipped Class: 80 min One Learning Session: 1 hour Written Reflection
Teaching Internship	2+	1-2	Staff Meeting: 1 hour Multiple Learning Sessions: 2-4 hours Written Reflection
Teaching a Chemistry Lab	1+	3	Lab Training: 3 hours Teaching: 3 hours

*Reproduced from Atieh et al.[1]

Both the Pedagogy Course and the Teaching Internship include an educational training component. Students in the Pedagogy Course (PC TIs) complete readings, activities, and assignments intended to provide a thorough background in numerous topics of chemistry and science education, including the theories of constructivism, mental models, metacognition, and multiple representations. Students in the Teaching Internship (non-PC TIs), however, primarily receive training focused on best practices, such as ways to get students to work together, how to construct effective questions, and how to scaffold learning. During the duration of this study, the author (E.L.A.) was the instructor for both courses. Concerning the teaching components, PC TIs typically only hold one office hour per week, while the non-PC TIs hold approximately two learning sessions per week, in the form of office hours, workshops, review sessions, or acting as facilitators in the new face-to-face active learning recitations.

Methods

Observations

Observations of six Teaching Interns in their office hours were conducted over four semesters, spanning Fall 2016 to Spring 2019. These TIs were each observed during their second week in the program, and then again at varying intervals: two TIs each were recorded over one semester, one year, or two years as a TI. The TIs that were selected for this analysis were chosen at random, controlling for gender and whether or not they enrolled in the Pedagogy Course, where possible. However, being that most multi-year TIs "graduate" into holding other learning sessions, such as workshops, the opportunities to observe the same TI over extended periods of time in their office hours was limited.

The room in which office hours are conducted is a large, open room full of tables and serves as a popular group study space. Several courses host their office hours in this room. The TIs have two large tables and a white board reserved for 6 hours each weekday, with one TI per hour. Students are allowed to drop in at any time without advanced notice. Usual attendance includes 3-5 students at any given time, although it is not uncommon to see upwards of 10-12 students at once during the weeks of exams. Being a shared room, video data collection was not be suitable for privacy reasons. The possibility of students being deterred from extra help because of the video recordings also raised ethical concerns. Instead, audio data was collected using a small, hand-held device. The observer (E.L.A) also took written notes on a laptop to keep track of the speakers, nonverbal behaviors, and other details which may have otherwise been ambiguous.

Audio data was transcribed verbatim with timestamps by the author (E.L.A.) using NVivo version 11. A sampling technique was used to analyze the data, in part because recording was limited only to General Chemistry students who also consented to participate in the research study. In order to allow the TI to acclimate to the observation, the first five minutes of the office hour are excluded from analysis.

Afterwards, ten minutes from the beginning of the office hour and the final ten minutes are coded. If extraordinary differences between the two sets of data arose, an additional 5 minutes of data would be included in the analysis. This back-up plan was not necessary for the data presented in this study.

Analysis of Transcripts

Cole et al. state that the selection of a unit of analysis is a key step in discourse studies.[124] Units of analysis are the individual portions that are coded and may include complete thoughts or sentences, turns of speech, or time. Casual dialogue, such as that found in these observations, does not always include complete sentences, and quantifying a “complete thought” would be subjective. Using the turns of speech as a unit had the potential to mislead as well. For example, lengthy explanations by the TI would be obscured by coding it as a single turn. As this study aimed to provide a snapshot of how the TI spent their time in the office hour, it was most reasonable to use length of time as the unit of analysis.

Open-coding of the audio data consisted of a short description of the TIs’ and students’ actions or type of speech (e.g., asking a question, giving advice, etc.). Upon discussion with the second researcher (D.M.Y.), a second round of coding was performed to further clarify these actions and speech using a fine (e.g., asking a recall question, giving course advice). This coding scheme was organized and placed into a spreadsheet that with examples for training. The second researcher coded approximately 15% of the data chosen at random from each TI. The initial overall agreement was around 81%. After modifying some of the definitions and discussing each of the discrepancies, a full agreement on the coding scheme was attained. The full coding scheme can be found in the Supporting Information Table 4.S1 along with examples of each.

As described in the Background of this paper, discourse was analyzed using three different dimensions, each of which describe some component of the information being communicated. These dimensions are visualized in Figure 4.1.

Dimensions of Discourse			
Direction	**Type**	**Depth**	**Example (TI dialogue)**
Dialogic	Knowledge	Deep	*What's something you know by looking at this graph?*
		Shallow	*Is this an ionic or covalent bond?*
	Common Ground		*So, are you saying this wouldn't produce a precipitate?*
Monologic	Knowledge	Deep	*You can tell that this isn't going to matter because they're both moving at the same rate*
		Shallow	*So to do this one, you're going to need the velocity, mass, and Planck's constant.*
	Common Ground		*Remember, we already said this side is positive.*
Noninteractive			*[TI solves a problem on their own, without demonstrating to the student]*

Figure 4.1. The hierarchy of the three dimensions of discourse used to describe TI office hours.

The first dimension of discourse sought to address Research Question 1, determining whether TIs adjusted their speech to allow information to flow both ways or if they predominantly spoke at the student. Being that the system of interest in this study is the TIs, discourse is described in relation to them. That is, discourse was classified as "monologic" if the information given by the TI to the student was strictly intended to deliver a specific message.[134] Discourse was coded as "dialogic" if the TI was actively eliciting verbal participation from the student, such as through questioning or prompting. If no information was being communicated or elicited (such as a TI trying to solve a problem independently), the action was coded as "noninteractive."

The second dimension used to analyze the data is based on the type of information being communicated. Information was classified as "knowledge" if new information was being shared or elicited by the TI. For example, if a TI initiated an explanation of some chemical phenomenon, this was coded as "knowledge." The remainder of information involved the revoicing of previously-discussed knowledge and questions to check mutual understanding. This was coded as "common ground."

The "knowledge" code was further dissected based on a final dimension: depth. This dimension emerged as it became evident that some TI-initiated questions required a greater understanding from the students ("deep") when compared to recall questions (“shallow”). Questions posed by the TIs were classified under one of 16 types described by Graesser and Person.[130] The required length of response[130] and number of possible answers was used to categorize knowledge questions as deep or shallow (Table 4.2). Questions requiring both long answers and for which there were multiple possible answers were considered “deep” knowledge, while “shallow” questions met neither or only one of these requirements. Specific examples of each question type can be found in Table 4.S2 of Supporting Information.

Table 4.2. Classification of TI Question Types

Question Type*	Length of Response	Number of Possible Correct Responses	Depth
Verification	Short	Single	Shallow
Disjunctive	Short	Single	Shallow
Concept completion	Short	Single	Shallow
Example	Long	Multiple	Deep
Feature specification	Short	Single	Shallow
Quantification	Short	Single	Shallow
Definition	Long	Single	Shallow
Comparison	Long	Multiple	Deep
Interpretation	Long	Multiple	Deep
Causal antecedent	Long	Multiple	Deep
Causal consequence	Long	Multiple	Deep
Goal orientation	Long	Multiple	Deep
Instrumental/procedural	Long	Multiple	Deep
Enablement	Long	Multiple	Deep
Expectation	Long	Multiple	Deep
Judgmental	Long	Multiple	Deep

**Question types adapted from Graesser and Person*[130]

Written Reflections

Each week, TIs submit a written reflection post to a forum on the course management site. These posts are visible to the other TIs and each TI is required to comment on at least one of their classmates’ posts per week. Reflection posts are semi-guided and generally include open-ended questions about their key takeaways from their learning sessions and weekly training (or the Pedagogy Course). A sample prompt can be found in the Supporting Information. Reflection posts were analyzed for each of the TIs in this study, primarily focusing on the ways TIs describe their roles, teaching beliefs, and personal changes that they have noticed in themselves.

IRB

All methods and procedures discussed herein were granted IRB approval under protocol #15-813M with annual renewal. All participants in this study provided their informed consent. General Chemistry students were given the option to participate or abstain at the beginning of the semester. As they signed in to the office hour upon arrival, their names were cross-checked to determine whether or not they had offered their consent. Without consent, the audio recordings were ceased. All participants were informed of their right to withdraw completely from the study or choose to not participate in a particular component at any time without any detriment to their grade or academic standing.

Charlie and Theo – 1 Semester

Observations

Theo and Charlie both began in the Fall 2016 semester as TIs. Theo was enrolled in the Pedagogy Course, while Charlie was not. Both TIs began with very similar discourse profiles (Figure 4.2). Just about half of their earlier office hour consisted of monologic discourse, with the bulk of that time described as shallow knowledge. In contrast, less than one-fifth of their sessions were dialogic. Even when they were eliciting information from students, it was primarily in the form of shallow questions, such as "What makes up the atomic mass?" Notably, student dialogue and actions represented a similar proportion as the dialogic discourse. While Theo was coded as having more noninteractive time, both TIs spent a nontrivial amount of time solving problems on their own, before deciding to interact with students. This behavior is most common when a TI is insecure in their content knowledge or otherwise worried about making a mistake in front of the student.

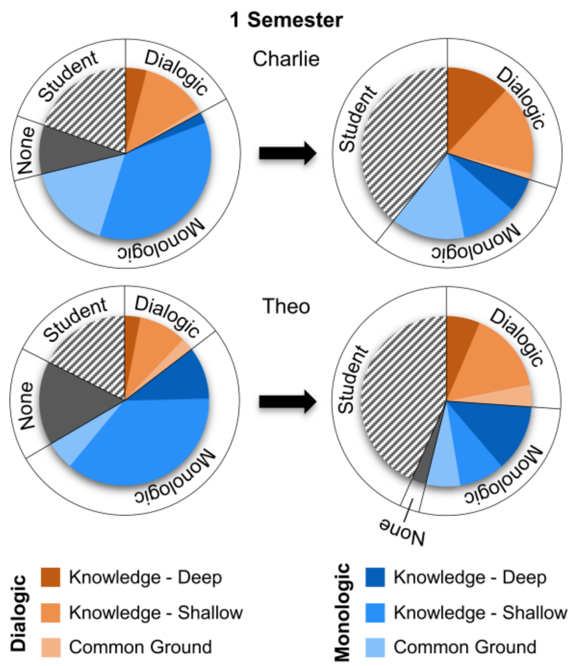


Figure 4.2. A comparison of the type of discourse in Charlie's (top) and Theo's (bottom) office hours. The pie charts on the left represent the first observation, while the pie charts on the right represent the second observation 1 semester later.

Table 4.3. Change in TI Discourse (One Semester)

	Δ% of Total Discourse*	
Discourse	Charlie	Theo
Dialogic	12.8	11.5
Monologic	-23.3	-24.2
Student	19.6	25.9
None	-9.2	-13.2

*Change in percentage of total discourse from the 1st observation to the 2nd observation (i.e., post-pre)

After only one semester, a positive change in the student dialogue is clear. Being that the amount of monologic discourse dropped by nearly half of its original amount for both TIs, it is reasonable that the amount of student-generated activity jumps accordingly. Further, within the monologic discourse category, deep knowledge and common ground constituted a greater proportion when compared to the first observation. Charlie did not have any evidence of noninteractive time coded, while Theo had very little in comparison to his first office hour. Although their dialogic discourse did increase, both TIs were still predominantly asking shallow knowledge questions, and common ground remained more likely to be established by the TI (monologic) rather than elicited (dialogic). Table 4.3 provides the overall change in percentage (Δ%) of the total discourse for Charlie and Theo, while Tables 4.S3 and 4.S4 (Supporting Information) provide the complete raw data for each TI.

Reflections

Over the course of one semester, Charlie (Box 4.1) and Theo (Box 4.2) both reflected on their learning sessions and what they had taken away from the weekly TI meetings and Pedagogy Course, respectively. During the first week, they were asked to describe their general teaching approach. Both Charlie and Theo state that they want their students to "understand" the material and believe in guiding the students, although it is not clear exactly what is meant by these terms. Theo does expand somewhat on his strategy, stating that he only wants to use a "small amount of direction" but will redirect students if they are "so far off." He also states that he seeks to improve his own knowledge so that others can understand his thinking. Both TIs appear to imply that part of their role is to hold the correct knowledge and then lead students to the same understanding.

During the week of their first observations (Week 2), both TIs describe their office hours and challenges they faced. Charlie was confident in his ability to answer students' questions effectively and suggests that his approach to problem-solving is "more organized and understandable." This is consistent with the results of his discourse analysis, which was predominantly monologic (Figure 4.2). While he does indicate that he values student understanding (via assessment), this was not something he was able to practically do. Instead, it appears his first priority was in communicating his knowledge on the topic first.

Box 4.1: Reflection Passages from Charlie

Week 1: *My [strategy] is to guide a student into a mindset in which he/she understands what is being asked and to understand what the formulas mean.*

Week 2 [1st Observation]: *I felt very prepared and was able to answer the questions in an effective manner. I was also able to give insight on how I personally set up a problem to show the student a more organized and understandable approach... I did not have time to give a practice question, so I cannot be sure if he actually understood the question*

Week 5: [From the weekly TI meeting] *It is much easier to learn new material if you can connect it to something you already understand and if I can try and find these connections in the students I help, then it should help them grasp certain concepts quicker and with more comprehension*

Week 8: *Many [TIs] asked a lot of preliminary questions before even starting the [practice problem]…It seems like something I might want to spend more time on because understanding the roots of the problem is very important.*

Week 11: *It is important to guide the students towards the answers instead of just telling them how to do it…I think students learn when they apply their own problem solving skills to test knowledge. This process can be facilitated with guidance from others but even so, effective learning will not occur unless the student puts in effort as well*

Week 14 [2nd Observation]: *I have noticed that I try a lot harder to guide the student into giving each part of the answer as opposed to when I used to explain what to do and check to see if they understood. By having the student answer each part, it helps to see where they may be struggling exactly and to see if they are actually following along…*

[On changes they've noticed in themselves]: *I have become a bit more personable. I try much harder to make it "our" problem to solve and not just the students. I make a conscious effort to use words like "we" or "lets do this" in hopes that the student will be more engaged and it seems to be effective.*

Following Theo's first observed office hour (Week 2), he uses his reflection space to describe one challenge that arose when his expectations of a student did not align with reality. This particular interaction was not part of the discourse that was analyzed and documented in Figure 4.2. He found that while he tried to "explain" electron configurations, she lacked some of the foundational pieces of knowledge. It is not possible to infer Theo's feelings from this interaction (e.g. frustrated, empathetic, concerned, etc.), and it is also unclear as to what specific steps he took leading up to this exchange. For example, use of an "explain" approach (monologic) may have been a strategy he resorted to only once he realized the student's baseline knowledge on electronic structure was lacking. Nonetheless, the predominance of monologic discourse

Box 4.2: Reflection Passages from Theo

Week 1: *I'm not one to lead people to the answer but have them get there with a small amount of direction, but if they are so far off, then I will redirect them…I hope to learn how I can improve my knowledge in such a way to be able to get others to understand what I am thinking too.*

Week 2 [1st Observation]: *I had a student come to my office hours with some relatively simple questions that turned into me discovering that her previous knowledge of some of the basic concepts was absent. Trying to explain election configuration when the student does not know how many electrons are in an atom or what valence electrons are, can make it an uphill battle.*

Week 5: *I am trying to move away from presenting material to students and for them to start learning on their own and making their own assumptions and conclusions with me guiding them there.*

Week 8: *I saw a fellow TI redirect a student's alternate conception in a very effective yet positive way which was exactly how we discussed in class which I hope to help improve on*

Week 11: [On what a successful office hour looks like] *The TI would first establish what the student's knowledge of the topic is and where they have gaps. Then the TI would attempt to clarify some alternate conceptions, and have the student ask questions. Finally the TI would challenge the student [and] require the student to reflect on what they just talked about.*

Week 14 [2nd Observation]: *Several students were having difficulty with understanding the concept of molarity. So I had gotten them to walk me through a problem…What was good about this was that where one student had struggled understanding the topic, another was able to help. We walked through the entire problem together.*

[On changes they've noticed in themselves]: How to be a more positive and encouraging teacher…I have grown to realize that if I create an environment of joyfulness then the students are more likely to work on the problems and attempt to think about the topics rather than just get the answer. They start to enjoy the material and the reward of understanding the concepts. I am more content with teaching …because I can see how in some people's mind certain "incorrect" ideas are only alternate conceptions.

observed and the limited student dialogue illustrated in Figure 4.2 suggest that Theo relied on mainly on explanations to exchange knowledge, contrasting with his espoused strategy of only employing "a small amount of direction" as stated in Week 1.

Over the weeks, Charlie and Theo reflect on the knowledge or strategies they wish to incorporate into their own teaching. In some instances, these changes are informed by topics discussed in weekly training (Charlie, Week 5), while others stem from in-class "practice office hours" with other TIs (both, Week 8). In Week 5, Charlie's key takeaway from the TI meeting is the idea of ascertaining and using a students' prior knowledge to make conceptual connections (i.e., Meaningful Learning[7]). This approach is echoed in Week 8, where he considers how to incorporate more questioning in order to achieve this goal, and again in Week 11, as he emphasizes the importance of student initiative in their learning. Theo describes a similar pattern of recognizing his unidirectional approach to teaching (Week 5) and discusses the ways he would like to change. A common theme in both Week 8 and 11 is alternate conceptions, which was the topic of Week 4 in the Pedagogy Course. It is noteworthy that he discusses this twice, along with invoking similar Meaningful Learning ideas as Charlie (i.e., ascertaining student's prior knowledge in Week 11), given Theo's reflection of his first observation in which he failed to initially determine his student's prior knowledge and struggled with her lack of background knowledge. Following their second observation, both TIs describe problem-solving in solidarity with their students and suggest that their focus has shifted from transmission of the correct information to the building of knowledge with their students.

In addition to their teaching approaches, both Theo and Charlie describe strikingly similar interpersonal changes that resulted from their experience as TIs. Charlie recounts a practice that was explicitly discussed during the TI weekly meetings: the use of "we" in an effort to build trust. Theo writes that he had become more approachable and established a more amenable learning environment as a result. Both TIs believe that their students were receptive to these changes, which in turn made the students more willing to engage. In addition to their teaching approach, these interpersonal changes may have also led to the increase in student participation.

Noureen and Vidya – 1 Year

Observations

Neither Noureen nor Vidya had taken the Pedagogy Course during the course of this study. Noureen's initial office hour looked very much like that of Charlie's and Theo's, with nearly one-half of it coded as monologic discourse (Figure 4.3). However, one difference was that much of her monologic discourse was of deep knowledge. That is, Noureen provided reasoning behind the explanations for her students, rather than only facts. On the other hand, Vidya has the lowest proportion of monologic discourse of all of the TIs observed. However, she easily spent the most amount of time working independently. Looking at the transcript of her first office hour, her pattern was one in which a student would ask a question, she would solve it on her own to be sure she understood it, and then explain her steps.

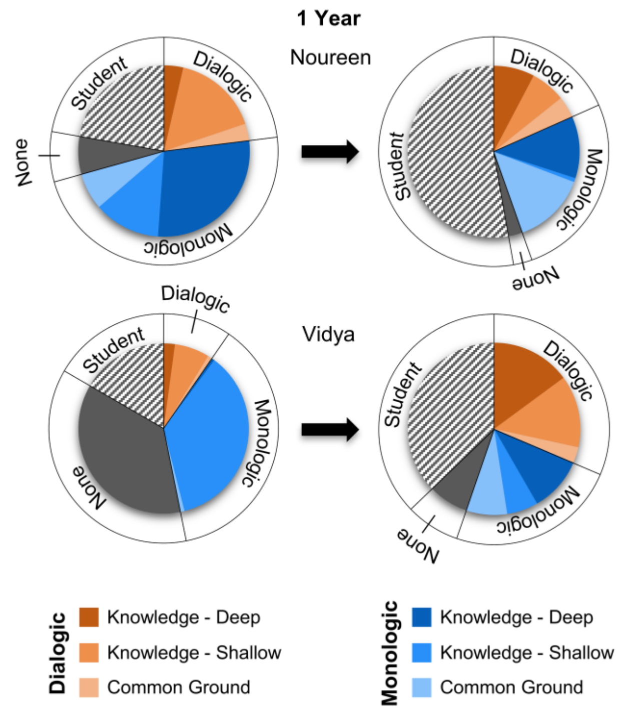


Figure 4.3. A comparison of the type of discourse in Noureen's (top) and Vidya's (bottom) office hours. The pie charts on the left represent the first observation, while the pie charts on the right represent the second observation after 1 academic year (2 semesters).

Table 4.4. Change in TI Discourse (One Year)

	Δ% of Total Discourse*	
Discourse	Noureen	Vidya
Dialogic	-4.7	21.8
Monologic	-21.4	-13.4
Student	30.6	20.5
None	-4.5	-28.9

*Change in percentage of total discourse from the 1st observation to the 2nd observation (i.e., post-pre)

Similar to Charlie and Theo, both Noureen and Vidya saw a marked increase in the amount of student dialogue and actions as their experience grew. After one year in the program, both TIs declined in the amount of noninteractive time, as well as in their monologic discourse. Although Noureen's dialogic discourse did not increase, she shifted toward asking deeper questions, which may in part explain the growth of student dialogue. This was true of Vidya as well, who also saw an increased use of dialogic discourse in general. Similarly, the amount of shallow knowledge given by these TIs during the office hours represented a smaller proportion of the overall monologic discourse in general. Table 4.4 lists the changes in overall percentage of discourse between the two observations.

Reflections

For the sake of brevity, the remainder of the TIs' reflection excerpts can be found in the Supporting Information (Boxes 4.3.1-4.6.2). The same reflection prompts were selected for each of the TIs' first semesters, but their final semester only investigates their reflections from every 5 weeks. Noureen began the TI program in a separate year and thus her reflection prompts had slight variations.

From the beginning, a common theme throughout Noureen's reflections is student engagement, as she stresses the importance of conversing with students versus "talking at them" (Box 4.3.1, Supporting Information). She writes that her aim is to be encouraging with students and to help them to feel comfortable with her. Although Noureen's first observation did include nearly 50% monologic discourse, in the end of her first semester, she writes that she is "better at leading a student to an answer" as opposed to "going straight to explaining the answer." Her goal of wanting to be encouraging is echoed in her first reflection of the second semester, in which she characterizes her students as her peers, rather than her students or tutees. Throughout her second semester as a TI (Box 4.3.2), she discusses her learning sessions as more student-centered, where she states that she asks follow-up questions, gives students space to express their thought processes, and enthusiastically awaits their "Aha!"

moments. These descriptions were more aligned with the discourse results from her second observation. Like Charlie and Theo, the words she uses to describe her teaching do not change significantly from one semester to the next; however, she is still able to recognize the changes in her teaching methods, which become more aligned with her beliefs over time.

Vidya's first observation (Box 4.4.1) stood out initially due to the large amount of time spent solving a problem on her own, without student interaction. In her reflection, Vidya discusses this situation somewhat, stating that it was a challenging problem and that she wishes she had taken her own chemistry notes to the office hour as a reference. Like Charlie, Vidya uses the word "guide" to explain her teaching strategy and says it can be just "giving them a simple hint." However, this does stand in contrast with her first observed office hour. Moving to her second semester, she expresses satisfaction in that her students were able to come up with answers on their own when she was offering minimal guidance, but she goes on to say that she still reverts to monologic discourse for students who do not have firm conceptual foundations. While she does state that her approach could have been different, it is noteworthy that she is able to differentiate the two scenarios and likely contributes to the more equitable share of dialogic and monologic discourse that was observed. Further, as Wells and Arauz[127] write, the goal is not to classify one form of discourse as good and the other as bad, but to acknowledge the purpose and value of both.

Eleanor and Nian – 2 Years

Observations

Both Eleanor and Nian were enrolled in the Pedagogy Course during the semester of their first observation. Eleanor's first session began with the largest amount of student dialogue of all of the TIs, though her dialogic discourse was less than average (Figure 4.4). Her monologic discourse was similar to most of the other TIs aside from the fact that she was coded as providing deep knowledge relatively more often. Nian began with an average amount of student dialogue in his first office hour, although like Eleanor, he utilized lower-than-average levels of dialogic discourse.

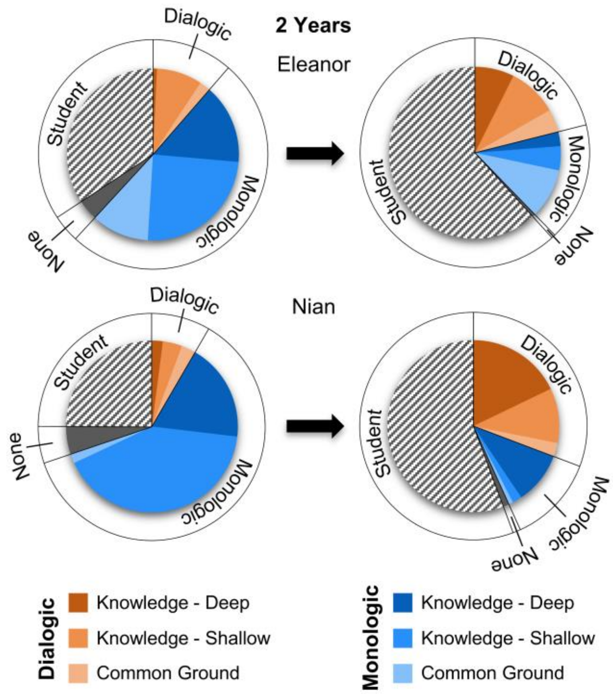


Figure 4.4. A comparison of the type of discourse in Eleanor's (top) and Nian's (bottom) office hours. The pie charts on the left represent the first observation, while the pie charts on the right represent the second observation after 2 academic years (4 semesters).

Table 4.5. Change in TI Discourse (Two Years)

	Δ% of Total Discourse*	
Discourse	Eleanor	Nian
Dialogic	9.7	22.4
Monologic	-33.8	-49
Student	27.5	30.7
None	-3.4	-4.1

*Change in percentage of total discourse from the 1st observation to the 2nd observation (i.e., post-pre)

Over two years in the program, this duo was found to have the largest proportions of student dialogue during their final office hours, as well as the lowest proportions of monologic discourse. Whereas Eleanor mainly used this monologic discourse as an opportunity to provide common ground, Nian instead primarily communicated deep knowledge through behaviors such as demonstrating reasoning. Both had improved in their ability to execute dialogic discourse at a deeper knowledge level, like Vidya and Noureen, which may have contributed to the increased student participation. Table 4.5 provides the changes in overall percentage between the two observations.

Reflections

Eleanor and Nian's reflection excerpts can be found in the Supporting Information under Boxes 4.5 and 4.6, respectively. Eleanor states that she has had prior tutoring experience, which informs some of her beliefs and her self-efficacy about teaching from the very beginning. Following her first observation, she appears to be cognizant of the amount of explaining she felt she was doing and states that she would like to move toward more "discussing." She attributes this difficulty to the student's lack of prior knowledge, but aims to learn how to improve her questioning abilities to remedy this. After one semester, Eleanor reflects on the fact that she now teaches less, in the sense that she asks more questions and gets the students to develop their own learning. Ironically, after her final observation in her second year as a TI, Eleanor write that she is still frustrated with her ability to engage students and her tendency to "lecture instead of encouraging students to explain their understanding." In fact, this was something she expressed multiple times throughout her second year's reflections (Week 5, Week 10). Despite her clear decline in monologic discourse, and the fact that her observation was the most student-centered of all the TIs, she was still very much aware of her monologic discourse. One possibility is that as Eleanor gained teaching experience and pedagogical knowledge, she became better-equipped in her self-monitoring skills and ability to judge her own learning sessions. That is, the more she learned, the better she became at identifying her faults.

In Nian's first reflection, discussing his general views on teaching, he writes that he enjoys "teaching and explaining so others learn and do not simply get questions right." (Box 4.6.1) However, he goes on to say that this task requires him to "think from different perspectives as well." While his satisfaction from explaining may help to explain the majority of monologic discourse from his first observation, he seemingly acknowledges student differences and the need to understand knowledge in different ways. This was a subtle difference from Theo and Charlie, who both expressed wanting to transmit their specific way of thinking to their students. Nian's aim to be open-minded remained a common theme throughout his first semester of reflection, stating that he also wants his students to consider multiple perspectives (Week 8) and that he learned to adapt his teaching based on his previous experiences (Week 14). This carried over to his last semester (Week 1) as well. As a second-year TI, Nian also acknowledges his shift towards student-centered learning (Weeks 10, 15) and even uses the phrase "we were able to work through it," a sentiment of solidarity also previously shared by Noureen and Charlie. Like Eleanor, even in light of his improvement, he still discusses changes that he could implement to improve as a TI.

Cross-Cutting Trends

Direction of Discourse

The previous sections of this work describe the manner in which TI-student discourse evolves over time. At the time of their first observations, all six TIs in this study were second-year science majors (3 pharmacy majors, 3 life science majors) and had not previously been TIs, nor had they reported any sort of formal pedagogical training when applying for the program. Still, this does not preclude individual differences in the data from their first observations. Each TI enters the program with their own beliefs about teaching and learning, shaped largely by their individual experiences with 12+ years of formal education, and they undoubtedly have variations in their communication skills and confidence levels. For this reason, caution should be exercised when interpreting results in order to avoid over-generalizations. Instead, the results presented here can be considered holistically, through comparisons across multiple sources of data, as well as between cases, in order to construct a more complete story.

Figure 4.5 summarizes the progression of all six TIs over time with regards to the first measured dimension of discourse, the direction of information. Generally speaking, a pattern emerges for all four categories as the TIs gain experience: increases in dialogic discourse (minus Noureen) and student dialogue/actions, with decreases in monologic discourse and noninteractive time. For all of the TIs, monologic discourse comprised the large block of time in their first observation, while dialogic discourse and student dialogue/actions were nearly equal in the first observation for all TIs except for Eleanor and Nian. Monologic discourse and student dialogue generally saw the largest shifts across all of the TIs.

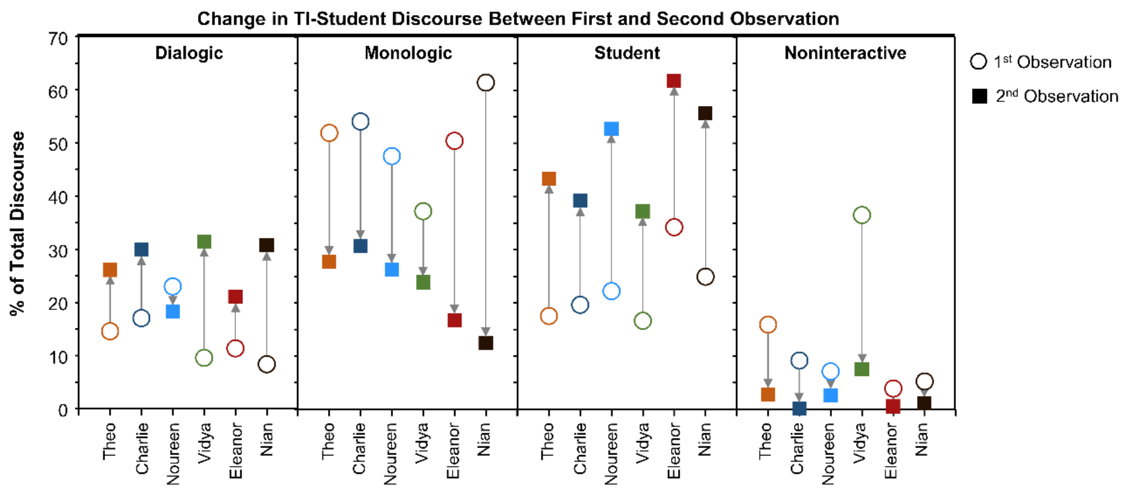


Figure 4.5. A summary of the changes in discourse between TIs and General Chemistry students, classified as dialogic, monologic, student dialogue/actions, or noninteractive. Open circles correspond to the percentage of total discourse (by length of time) that was coded in the first observation, whereas the solid-colored squares represent analogous data from the second observation.

Type and Depth of Discourse

Figure 4.6 provides additional data as to how the two dimensions of discourse, type and depth of information, changed over the course of these observations. In this figure, the data points represent the differences in the relative contributions of each discourse type/depth between the TIs' first and second observation. Specifically, the relative percentage of Knowledge-Deep, Knowledge-Shallow, and Common Ground was determined for both dialogic and monologic discourse. The difference between the relative percentages in the first and second observation is plotted on the graph. This method allowed for a comparison of these two dimensions across TIs, which may not have otherwise been possible if there were large differences in the total amounts of monologic and dialogic discourse. Being that the three data points in each TI "column" represent a relative change, the sum of these data points is 0.

Looking at these graphs, deep knowledge (triangles) saw the largest increase for all TIs in the dialogic category. Eleanor and Nian, the longest-serving TIs of the cohort, demonstrated the largest increases, while Theo and Charlie's shifts are the smallest. Interestingly, the relative amount of dialogic common ground (circles) did not seem to change in any meaningful way, with the exception of Nian. For both dialogic and monologic categories, all six TIs saw a decrease in the relative amount of shallow knowledge (squares) communicated. For most TIs, under monologic discourse, a decrease in shallow knowledge was accompanied by increases in both common ground and deep knowledge. However, for Noureen and Eleanor, only common ground demonstrated a relative increase. In fact, Noureen and Eleanor exhibited remarkably similar profiles in both the dialogic and monologic categories in Figure 4.6. With that, there were no clear trends apparent with regards to the changes in the composition of monologic discourse as related to the TIs' length in the program. Likewise, Theo, Nian, and Eleanor had each taken the Pedagogy Course as a part of the CCE program, though this factor also did not appear to contribute to any patterns seen in Figure 4.6. The full extent of the raw data can be found in Tables S3-S5 of the Supporting Information.

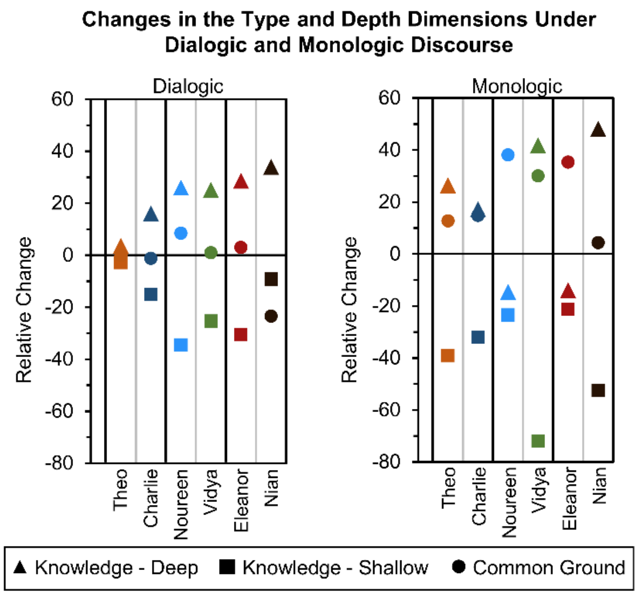


Figure 4.6. A summary of the changes in the type of information communicated by the TIs for both dialogic (left) and monologic (right) discourse. The amount in each of the three categories was calculated as a percentage of the total dialogic or monologic discourse. The graphed data here represents the difference in percent make-up between the first and second observation. For example, "Knowledge-Deep" constituted 78.2% of Nian's Monologic Discourse in his second observation, but only 30.1% in his first observation, for an increase of 48.1 (as shown on the graph).

Conclusions

The discourse analysis of observational data in this paper provide evidence of considerable changes in the dialogue of the Teaching Interns during their office hours, even in as little as one semester, regardless of whether or not they had taken the Pedagogy Course. However, in their reflections, both PC and non-PC TIs explicitly cite the topics and skills that they gained through their respective forms training, indicating that they are essential components of the CCE and TI programs. The six TIs in this multi-case study began their role as a TI with similar beliefs and dialogue patterns. Potentially due to their prior success in the course, most of the TIs did indicate wanting their students to develop deeper understandings of the material, as opposed to using rote memorization. However, all six TIs primarily engaged in monologic discourse to convey knowledge to students, while any dialogic discourse mainly consisted of asking low-level recall questions. Further, several of the TIs used a measurable portion of the office hour to prepare or solve problems independently before engaging with their students, likely due to a lack of confidence or deficiency in their content knowledge.

Concerning the first research question, all six TIs demonstrated shifts in the overall direction of communication during their office hours. Perhaps the most obvious change is that of the student discourse and activity, which averaged approximately 22.5% of the total observation time in the first observation of the TIs and 48.3% at the second observation. The amount of dialogic discourse increased by nearly two-fold or more for all but one TI (Noureen), regardless of their length in the TI/CCE programs. Monologic discourse, however, did tend to slowly decline overall as TIs gained more experience, with the second-year TIs utilizing it the least. As far as the content of the dialogue (Research Question #2), the TIs generally shifted from low quality knowledge to high quality knowledge, both in their explanations and in their questioning. Further, the more experienced TIs asked higher-level questions at a greater rate. However, there were no clear trends with common ground questions in either the dialogic or monologic category.

For the final research question, a look at TIs' reflections over time was used to compare their perspectives on teaching with that which was observed. TIs in their first semester of teaching used similar language to describe their teaching strategies. Several used the word "guide" to describe their approach, indicating their desire to facilitate student learning. Several of the TIs specifically mentioned wanting to help their students to understand the material rather than memorize how to solve problems. However, monologic discourse made up an average of 50.5% of the time of their first observation, while dialogic discourse only constituted an average of 14.0%. Likewise, the majority of questions and explanations were of low-level knowledge, focusing on superficial features of a problem or topic rather than conceptual understanding and analysis. For these reasons, it appears that the TIs' practical theories and espoused theories are incongruent when they begin the TI program. Even though they do hold fairly sound theories about learning, it is likely that they struggle with actually putting those ideas into practice. As Buitnik described, many new teachers focus on classroom management before they can shift their focus to student learning.[131] While the TIs may hold positive attitudes about learning prior to their first learning session, their lack of experience means they struggle more with logistics, such as time management (Charlie), dealing with multiple students (Noureen), and ensuring that they have the proper resources (Vidya). However, while the TIs espoused theories did not appear to change drastically, the TIs not only improved in their ability to engage the students and ask a wider range of questions, but they were also able to identify the specific changes in their teaching behaviors.

Implications for Peer Instructor Training

This research provides insight into how Teaching Interns in General Chemistry change their teaching behaviors over time and how they describe those changes. At least some of these changes can be attributed to the TIs' weekly training, suggesting that perceive value in the weekly meetings and Pedagogy Course. From both the observations and their written reflections, the following suggestions are offered for future pedagogical training.

The first is to explicitly remind peer instructors to allow a student more time to answer their questions. While transcribing observations, the TIs often would answer their own question immediately or in under two seconds. One possibility is that they feel as though their question was of unclear or of poor quality and they wanted to avoid furthering the student's confusion. It is also possible that they simply feel uncomfortable sitting in silence so they fill the airwaves with the answer instead. It is worth noting that these two possibilities are not mutually exclusive. Peer instructors should not only be reminded of this fact, but they should also be given a chance to practice mitigating these issues during training. It may seem humorous at first, but affording them the opportunity to sit in silence for several seconds after asking a question may allow them to realize the silence is not as terrifying as they may have thought.

A second recommendation is to discuss effective questioning, allowing peer instructors to create diverse questions and consider how to scaffold them. Bloom's taxonomy may be a helpful place to start, so that students can understand what is meant by “higher level questions.”[135, 136] They should also consider the differences between open- and closed-questioning, and which question types are best for different scenarios. For example, closed recall questions may be most suitable to initially gauge a student’s prior knowledge. On the other hand, open-ended questions in which students are asked to compare two ideas or to make judgements about an answer are most productive once students have demonstrated a foundation of knowledge in order to build a deeper understanding.

Limitations and Future Directions

This study utilized two different forms of qualitative data collection to perform a multi-case study on the peer instructors within the Rutgers General Chemistry course sequence. The purpose of a case study is to allow researchers to narrow the number of participants in favor of conducting a deeper probe. However, it is recommended that follow-up studies are performed to examine the generalizability of the results. Likewise, interview data would be useful to not only further engage with the TIs about their beliefs and perceptions of their learning sessions, but they would also allow the researcher to understand the origin of the TIs’ beliefs and changes in behavior. Typically, course evaluations of the TI program and Pedagogy Course only ask TIs about their perceived helpfulness of topics. Whereas a combination of observations, reflections, and interview data would provide a more thorough sense of the methods and pedagogy topics most valuable for training future peer instructors.

Supporting Information for Chapter 4

Sample Reflection Prompt

Instructions:
Each week, you will submit a post under "Forums" consisting of the following 3 parts (when applicable). Each part should be separated from the other part and clearly indicated (such as with a title of some sort).

Part I. Learning Sessions:

1. How did your learning sessions go this week?
2. What was one specific thing you think could have gone better?

Part II. Weekly Meeting:

1. What was your main takeaway from the weekly meeting this past week?

Part III. Miscellaneous Prompt

1. How do you think students learn best?

Additional Data

*Box 4.3.1: Reflection Passages from Noureen (Semester 1)**

Week 1: *I believe that when teaching, it is important to have a conversation with your students instead of talking at them. It is imperative to ask them how they feel about the material, if they have any questions, or simply their opinions on certain topics. In my opinion, teachers should be able to converse with students in order to make them feel comfortable with asking for help.*

Week 2 [1st Observation]: *I conducted my office hours a little differently this week due to the surplus of students by encouraging them to help each other and doing most of the problems on the board in order to involve as many students as possible*

Week 5: *One student that came to office hours was very enthusiastic about chemistry, asked a lot of questions, and was able to understand the concepts she was having difficulty with. Overall, I was able to converse with her as peers while helping her with some work.*

Week 8: *This week, I feel like my office hours went very well. About three students showed up and we were all able to work together, use the blackboard, and teach one another the material instead of the usual "I have a homework question that I need specific help with." I felt as if we were all able to come together which made the office hours very effective.*

Week 14: *After almost a semester of participating in the TI program, I feel like my teaching skills have grown tremendously. I am more aware of how to approach a student effectively by understanding their struggles. Most importantly, I am better at leading a student to an answer and building off their previous knowledge instead of going straight to explaining the answer.*

*Noureen had slightly different reflection prompts due to the semester she began

Box 4.3.2: Reflection Passages from Noureen (Semester 2)

Week 1: *One strength I believe I have in regards to being a TI is treating the students as a peer instead of my tutee or student. I find it enjoyable to ask the students about their day and their comfort level in chemistry instead of spending my whole learning session lecturing at them. I think the students feel more comfortable and calm when the TI is able to relate to their struggles*

Week 5: *Students sometimes just agree with my explanation when I don't think they understand what I am saying. I always try to ask them follow up questions so I can assess if I am actually making sense to them*

Week 10: *When I was first a TI, I found myself always wanting to explain the concept if a student did not understand or had trouble. But now, I find it more effective to let them fully explain something [their way] and try to let them pinpoint where they went wrong instead of intervening in the beginning. By talking out loud and explaining to me their thought process, students are often able to correct themselves and I believe it is more effective that way.*

Week 14 [2nd Observation]: *My office hours went well this week…we were able to work on last year's exam and work out problems on the whiteboard. I feel like I am doing a good job with a student when they have an "Aha!" moment...It is an amazing feeling when you see a student connect the dots and understand a difficult topic.*

[On changes they've noticed in themselves]: *When I was new to the TI program, I was less confident in my teaching ability and felt like I was doing something wrong. Now, I am more confident in my learning sessions and I understand what I need to do in order to help my students. Overall, I think I have made a lot of improvement. I think my confidence level has skyrocketed since the beginning as I feel more familiar with teaching, articulating my thoughts, and just simply communicating with students.*

Box 4.1: Reflection Passages from Vidya (Semester 1)

Week 1: *My teaching philosophy would be to guide the student only until a point where they can figure what is asked in the question. It is just like giving them a simple hint.*

Week 2 [1st Observation]: *Although there was one challenging question that took up a lot of time, I did explain the steps to follow but did not reach the answer, so the next TI came and I told her what I think we should do…Overall it went well, and we figured out the problem as well…I think I should have taken my old notes with me, which would be helpful to refer to.*

Week 5: *My office hours went well. I enjoyed helping them and most of them were able to come up with the solution if a hint was given… There were students who did not know how to do the problems at all, so I tried getting it out of them but there was no point as they did not have a solid understanding of the concept. So I did tell them how to do it, but instead I could have explained the concept and then asked them to solve on their own.*

Week 8: [From observing other TIs] *I think it is definitely a great idea to let the students come up to the board and do the problems. I would implement that in my office hours.*

Week 11: [On what a successful office hour looks like] *A successful learning session involves minimal talking on part of the TI and a lot of thinking, talking and working in groups on part of the students. The TI's role involves listening to what the student is saying and making sure it is right and when necessary to correct them and give the right concepts.*

Week 14: *My first semester being a TI has been very eventful. I got to learn a great deal from the students and TIs I worked with. There have been many instances when a student understands a concept only because a TI or a friend explains it to them and that has happened a lot with me. I get a number of students who seem very confused about a topic and I try to explain it to them and give examples. That is when they go like 'ahh, that makes so much more sense'. It really makes me happy when they are able to follow what I say and then work from there.*

[On changes they've noticed in themselves]: *I got to learn a lot about effective teaching which I did not know a great deal about before I was a TI. Being enthusiastic about what I teach, trying to truly connect with students on the basis of what they know in chemistry and being confident and friendly are some of the many things I got to learn this semester.*

Box 4.2: Reflection Passages from Vidya (Semester 2)

Week 1: *I think really getting a sense of where the student stands in understanding the concepts and then taking from there will help me become a good TI. Also helping the students work through the problem and clearing their doubts are also some other factors.*

Week 5: *My office hours went well. I enjoyed helping them and most of them were able to come up with the solution if a hint was given… There were students who did not know how to do the problems at all, so I tried getting it out of them but there was no point as they did not have a solid understanding of the concept. So I did tell them how to do it, but instead I could have explained the concept and then asked them to solve on their own.*

Week 10: *In office hours, if a student has already done a problem I would let them explain it to the student who has trouble doing that problem. I do think I have been encouraging students to work in groups or through discussions since it the best way of learning.*

Week 15 [2nd Observation]: *Office hours went well. There were a lot of students this time. Most of them were preparing for their exam. Since it took me time to reach to every student because there were a lot of them, I saw there were many who started working in groups and helping each other, which was nice.*

[On changes they've noticed in themselves]: *There was something to learn from every meeting and it all went towards becoming a better TI, instructor and mentor. For me practice office hours were the most memorable. Though they were very anxiety causing I got to learn a lot by just looking at how others taught and also got to learn from my as well as others mistakes. To be able to recognize where the student stands in his/her understanding of the subject and finding common grounds to talk about it is one of the most important things that I have learned as a TI. I have been able to incorporate many of the things that we have discussed through the weeks and have seen myself grow as a TI since the beginning.*

Box 4.5.1: Reflection Passages from Eleanor (Semester 1)

Week 1: [In prior tutoring experiences] *I find myself having difficulty explaining concepts that make sense in my head, because I fail to realize that everyone learns and understands concepts in different ways. In addition, I tend to keep my thoughts to myself when working through problems, so I need to be able to verbalize these thoughts in order to become an effective tutor.*

Week 2 [1st Observation]: *We approached the problem step-by-step, and the student was able to grasp onto the importance of writing down every step with units to prevent calculation errors. The one thing I wish I had done differently was to do less explaining and more discussing. When I tried asking the student what she thought the next step in the problem would be, she could not give me an answer. In this week's learning session, I hope to be able to ask more specific questions that will encourage discussion instead of lecturing.*

Week 5: *I felt that I could answer most of the questions he had and cleared up his confusion with most concepts. However… I hope to improve my ability to clearly explain concepts to others.*

Week 8: [From observing other TIs] *I still find myself to be much more univocal than dialogic in my teaching approach. I remind myself that I need to ask more questions, but I've found that it's quite difficult to change old habits.*

Week 11: [On what a successful office hour looks like] *A successful learning session is one in which the TI and students are carrying out dialogic discourse. In other words, the TI should not be lecturing, unless the student demonstrates no basic understanding of the concept. This type of foundation is necessary for students to work on problems together and ask the TI questions, which the TI can respond to with concise explanations, visual representations, practice problems, and more questions for the students.*

Week 14: *The biggest change I've noticed about my teaching is, ironically, that I do not teach as much as I used to. In other words, I tend to ask more questions to students in a way that pushes them to learn concepts on their own. However, I would like to improve my ability to work with a large group of students at once.*

[On changes they've noticed in themselves]: *I think one of the biggest changes I've noticed about myself is that I've gotten better at putting my thoughts into words through this experience. It always feels great when I see students grasping concepts of confusion or when they say things like "You made that much easier than I thought it was."*

Box 4.5.2: Reflection Passages from Eleanor (Semester 4)

Week 1: *I would like to learn how to accurately gauge a student's knowledge level or understanding of a topic.*

Week 5: *As a TI, I rarely ask questions that make students really think about why something is the way it is. In this way, I tend to stay at the lower levels of Bloom's taxonomy. This may be because some concepts are too complex to explain that I resort to rote memorization.*

Week 10: *My office hour this week went well. Students had the most trouble with drawing Lewis structures and organic chemistry naming. Something I still struggle to do is avoid lecturing students. When students ask me questions about general topics, I find myself trying to teach instead of facilitating learning.*

Week 15 [2nd Observation]: *I tried to get students involved by having them answer questions and write things on the board every few minutes. I still struggle with being engaging with students when they ask me to explain general concepts. In these situations, I tend to lecture instead of encouraging students to explain their understanding.*

[On changes they've noticed in themselves]: *I feel that I have learned how to approach problems that I do not immediately know how to solve and work through them with students in a much more calm manner than before. I've learned that it's okay to make mistakes in front of students.*

Box 4.6.1: Reflection Passages from Nian (Semester 1)

Week 1: *I like teaching and explaining so others learn and do not simply get questions right; this requires me to think from different perspectives as well.*

Week 2 [1st Observation]: *I worked with [a student] on stoichiometry conversions and was able to provide a lot of tips on how I used to solve the problems. The student was on the right track and I was able to guide him to the finish line with a little bit of help here and there. Although I thought it went very well, I wish I had given the student had more complex problems because he had a decent understanding.*

Week 5: *My learning sessions this week went well. All three students were doing well and I only had to assist them a little bit. Although I had to guide them in the right direction every now and then, the students were confident in their work. Since it was the day before the exam, I also gave them a few tips for their first ever chemistry exam at Rutgers.*

Week 8: [From observing other TIs] *I would have students approach questions from different perspectives and have them explain to each other their problem solving strategies.*

Week 11: [On what a successful office hour looks like] *In my opinion, a good TI is one that is very approachable and willing to help students understand, not memorize. This TI would be very active with the students, making sure they are on the right track and providing help as necessary. A proper office hour should be one in which the TI is engaging with the students, having the students actively work together building off each other's ideas, and motivating students to learn. The TI needs to be prepared and enthusiastic about helping students.*

Week 14: *Over the weeks, I adapt to how I prepare for my sessions depending on the previous weeks, and still it is difficult to always be 100%. Additionally, after working with so many students, I feel that I improved my communication skills…The weekly meetings stressed the importance of engaged learning and in my teaching, I try to ask a lot of questions and have students make connections for themselves. To further improve myself, I would like to understand other teaching styles and methods that can work well in an office hour scenario*

Box 4.6.2: Reflection Passages from Nian (Semester 4)

Week 1: *I feel very comfortable being in the environment, and even more so, I feel good about the material. My own teaching beliefs align with helping the student thoroughly understand the material and be able to apply it, while also being able to think about the material in many different dimensions. To learn something the right away is not to memorize, but it is to master the topic and be able to think about it in abstract ways that forces the student to really ask questions that further their knowledge.*

Week 5: *One thing that always gives me trouble is when students come who are unmotivated to even attempt the questions. The student simply sit there and waits…I am always unsure how to deal with this situation, because there is always more to the story than the student being unmotivated. It could be a knowledge issue, a group issue, or simply the student being afraid to ask questions*

Week 10: *My learning sessions this week went well, I had a few students come in and ask questions about the homework. I was able to guide the students and then have them complete the majority of the questions on their own, which was nice.*

Week 15 [2nd Observation]: *I had students who asked about the Born Haber type problems, a bit on the tricky side, but we were able to work through it. Something I know I should be implementing is having the students use the whiteboard and explain their problem-solving methods to me. I do this at times, but in some situations, such as my past office hour, the students really are at a blank.*

[On changes they've noticed in themselves]: *Since I began the program my ideas have changed in many ways. I realized that all students really are different and a hundred different studying styles can yield similar results…I also learned that the "smartest" of students are not always the ones that get A's, many times I have seen students do extremely well on practice in learning sessions, but so many more factors come into play on test day.*

Table 4.S1. Coding Scheme and Discourse Categorization

			Code	Example
Dialogic	Knowledge	Deep	TI Asks Question (High Level)	Do you think this seems like a reasonable number?
			TI Directs Student to Solve Problem	So try it and tell me what you get
			TI Gives Student Problem to Solve (Independently)	Why don't you take a look at the next one, and then I'll come back in a few minutes
			TI Directs Student to Summarize Problem or Solution	Okay, so what have we determined already? So what is the problem asking?
			TI Directs Student to Explain Work	Tell me what you did so far.
		Shallow	TI Asks Question (Low Level)	First, do you think q is positive or negative?
			TI Directs Procedure for Student (Without Solving/Giving Answer)	So why don't you first try balancing the equation and tell me what you get?
			TI Provides Hint	Remember the rules about naming transition metals…
			TI Directs Students Attention	For this equation, why not take a look at the formula sheet?
			TI Prompts Student to Reconsider Answer	Well… why don't you try counting that again?
	Common Ground		TI Asks Student Initiating Question (Non-Content)	What are you currently working on?
			TI Asks for Clarification to Ensure Understanding	This number you wrote, what does that refer to?
			TI Asks Student if They Understand Prior Discussion	So does that make sense to you?
Monologic	Knowledge	Deep	TI Provides Advice in Chemistry	Always keep track of your units for these types of problems
			TI Provides Advice in Course	You should print the exam formula sheet out and use it with your homework so you get used to what's on it
			TI Provides General Advice	I would try to keep all of my notes and textbooks just for studying the MCAT
			TI Demonstrates Problem-Solving With Reasoning	If it was the same amount, we could just try canceling out both sides, but since they're not the same, just subtract the 3 from the 2.
			TI Explains Chemistry Concepts With Reasoning	Well I knew it couldn't be a zero-order reaction because the units didn't match up

		TI Provides General Plan for Solving (Non-specific)	Okay so basically, we're going to have to find out which reactant is limiting, and then use that as the starting amount to calculate the percent yield.
	Shallow	TI Explains Chemistry Concepts (No Reasoning)	According to kinetic molecular theory, the size of the particle won't matter.
		TI Explains Procedure (With Solving/Giving Answer)	So to balance it, put a 10 on this side, and a 5 over here.
		TI Asks a Question with the Answer	We know this is going to be positive, right?
		TI Solves Problem for Student Aloud	Okay so first let's cross this out [TI is writing]
		TI Asks Rhetorical Sense Question/Filler	We already said why this happens so this makes sense right?
		TI Summarizes Problem for Student	By excess, they mean the amount left over
	Common Ground	TI Looks for Resources for Student	[TI is searching for a section in the textbook for the student]
		TI Checks Student Work	[TI checks students work]
		TI Narrates as Student Works	[While student is writing] Yeah, so then we put the 2 in front of the O_2
		TI Reads Problem Aloud for Student	[TI reading problem text]
		TI Summarizes Their Finished Work	So, we said this one would be oxidized and we used the table to find the standard potentials, and then we subtracted them.
		TI Provides Constructive Feedback	You forgot to take into account the number of moles of sulfate
		TI Provides Positive Feedback	Yes, you balanced that perfectly!
		TI Confirms Student Response	Yes/No
Non-interactive		TI Reads Textbook/Notes Quietly	[TI reading to gain knowledge/understanding]
		TI Thinks Quietly*	[TI thinking quietly to self]
		TI Uses Calculator/Solves Problem Quietly	[TI using calculator to solve problem without showing student procedure]
Student		Student	Student asks question, gives response

*Coded at more than 3 seconds

Table 4.S2. Example of Each Question Type

Question Type*	Example
Low Level	
Verification	Do you need the mass of the electron?
Disjunctive	Will it be grams or kilograms?
Concept completion	What's the equation to relate wavelength and frequency?
Feature specification	What column is calcium in?
Quantification	What's the formal charge on the nitrogen?
Definition	What is the Heisenberg Uncertainty Principle?
High Level	
Example	Can you give me an example of an ionic compound?
Comparison	What's the difference between
Interpretation	So what does that [shape of the curve on a graph] mean?
Causal antecedent	What caused this to precipitate out?
Causal consequence	So if you increase the mass of the object, what's going to happen to the deBroglie wavelength?
Goal orientation	Why did you think it was better to put the neg charge on either of these?
Instrumental/procedural	How do you think we could maybe balance this?
Enablement	So what will help us determine the order of this reaction?
Expectation	N/A (none coded at this question type)
Judgmental	So do you think that answer sounds reasonable?

Table 4.S3. Percentage of Each Discourse Category Per TI Observation

TI Observation	Theo 1st	Theo 2nd	*Charlie* 1st	*Charlie* 2nd	*Noureen* 1st	*Noureen* 2nd	*Vidya* 1st	*Vidya* 2nd	*Eleanor* 1st	*Eleanor* 2nd	*Nian* 1st	*Nian* 2nd
Dialogic – Knowledge (Deep)	3.1	6.4	4.0	11.9	3.6	7.7	2.1	14.9	0.7	7.4	2.0	17.9
Dialogic – Knowledge (Shallow)	9.1	15.4	12.2	16.9	16.2	6.6	6.6	13.5	8.6	9.4	3.6	10.3
Dialogic – Common Ground	2.4	4.3	0.8	1.1	3.2	4.1	0.8	3.0	2.1	4.3	2.7	2.6
Dialogic – Total	**14.6**	**26.1**	**17.1**	**29.9**	**23.0**	**18.3**	**9.6**	**31.4**	**11.4**	**21.1**	**8.4**	**30.8**
Monologic – Knowledge (Deep)	10.0	12.7	2.1	6.5	28.1	11.6	0.5	10.3	15.0	2.7	18.5	9.8
Monologic – Knowledge (Shallow)	36.4	8.6	35.6	10.4	12.6	0.8	35.9	5.9	24.6	4.5	41.1	1.8
Monologic – Common Ground	5.5	6.5	16.4	13.9	7.0	13.9	0.8	7.7	10.9	9.4	1.8	0.9
Monologic - Total	**52.0**	**27.8**	**54.1**	**30.8**	**47.6**	**26.3**	**37.2**	**23.9**	**50.5**	**16.7**	**61.4**	**12.5**
Student Dialogue/Activity	17.5	43.4	19.7	39.3	22.2	52.8	16.6	37.2	34.2	61.7	24.9	55.7
Noninteractive	15.9	2.7	9.2	0.0	7.1	2.6	36.5	7.6	3.9	0.5	5.2	1.1

Table 4.S4. Relative Percentage of Each Information Sub-Type

TI Observation	Theo 1st	Theo 2nd	*Charlie* 1st	*Charlie* 2nd	*Noureen* 1st	*Noureen* 2nd	*Vidya* 1st	*Vidya* 2nd	*Eleanor* 1st	*Eleanor* 2nd	*Nian* 1st	*Nian* 2nd
Dialogic – Knowledge (Deep)	21.2	24.5	23.4	39.8	15.7	42.1	21.9	47.5	6.1	35.1	23.8	58.1
Dialogic – Knowledge (Shallow)	62.3	59.0	71.3	56.5	70.4	36.1	68.8	43.0	75.4	44.5	42.9	33.4
Dialogic – Common Ground	16.4	16.5	4.7	3.7	13.9	22.4	8.3	9.6	18.4	20.4	32.1	8.4
Dialogic – Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
Monologic – Knowledge (Deep)	19.2	45.7	3.9	21.2	59.0	44.1	1.3	43.1	29.7	16.2	30.1	78.4
Monologic – Knowledge (Shallow)	70.0	30.9	65.8	33.9	26.5	3.0	96.5	24.7	48.7	26.9	66.9	14.4
Monologic – Common Ground	10.6	23.4	30.3	45.3	14.7	52.9	2.2	32.2	21.6	56.3	2.9	7.2
Monologic - Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

Table 4.S5. Number of Each Question Asked by TI (First and Second Observations)

TI	Theo		*Charlie*		*Noureen*		*Vidya*		*Eleanor*		*Nian*	
Observation	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Low Level Questions												
Verification	0	1	1	3	3	0	0	2	0	0	0	0
Disjunctive	0	0	1	3	2	0	0	1	1	2	0	2
Concept completion	9	0	3	9	6	0	1	2	1	1	3	5
Feature specification	1	12	3	1	2	0	1	1	6	3	2	1
Quantification	0	5	1	0	0	10	0	0	1	0	0	0
Definition	0	0	3	0	2	0	0	2	1	0	0	1
SUM	**10**	**18**	**9**	**16**	15	**10**	**2**	**8**	**9**	**6**	**5**	**9**
High Level Questions												
Example	0	1	0	0	0	0	0	0	0	0	0	1
Comparison	0	2	0	1	0	0	0	1	0	0	0	2
Interpretation	0	3	1	2	0	0	0	2	0	3	0	2
Causal antecedent	0	0	0	0	0	0	0	0	0	0	0	2
Causal consequence	2	1	0	3	1	1	1	3	0	4	0	4
Goal orientation	0	0	0	4	0	3	0	2	0	1	0	1
Instrumental/procedural	0	0	2	0	2	7	0	2	0	0	1	1
Enablement	1	1	2	2	0	0	0	0	0	0	0	1
Expectation	0	0	0	0	0	0	0	0	0	0	0	0
Judgmental	0	1	0	1	0	0	0	0	0	0	0	0
SUM	**3**	**9**	**5**	**13**	3	**11**	**1**	**10**	**0**	**8**	**1**	**14**
Total Questions	**13**	**27**	**14**	**29**	**18**	**21**	**3**	**18**	**9**	**14**	**6**	**23**

Chapter 5 | Beneath the Surface: An Investigation of General Chemistry Students' Study Skills to Predict Course Outcomes

Abstract

As the conversation in higher education shifts from diversity to inclusion, the attrition rates of students in the STEM fields continues to be a point of discussion. Combined with the demand for expansion in the STEM workforce, various retention reforms have been proposed, implemented, and in some cases integrated into policy following evidence of success. Still, new findings, technological advances, and socio-cultural shifts inevitably necessitate an on-going investigation as to how students approach learning. Among other factors, students who enter college without effective study skills are at much greater risk of being unsuccessful in their coursework. In order to construct an equitable learning environment, a mechanism must be developed to provide underprepared students with access to resources or interventions designed to refine the skills they need to be successful in the course. Early, reliable assessments can provide predictions of individual student outcomes in order to guide the development and implementation of such targeted interventions. In the present study, a model is developed to predict students' odds of success based their study approaches, as measured by their responses to twelve survey items from a previously-validated instrument designed to measure students' deep and surface learning approaches. The model's prediction specificity ranges from 66.5% to 86.9% by semester. Two distinct sets of lower-performing students are identified in the data: those who align predominantly with surface approaches to learning versus those who indicate using both deep and surface approaches to learning. This supports the idea of a tailored approach to interventions, rather than a one-size-fits-all solution. Results from this instrument were correlated to students' reported study methods and beliefs, adding to the validity of the instrument.

Introduction

Educators and researchers alike have sought to ameliorate the attrition rates and "weed out" connotation of the STEM gateway (or gatekeeping) courses. Potential solutions to these problems have included placement exams and/or remedial coursework; however, these measures may introduce financial burdens, time constraints, and other barriers that disproportionately impact students of non-traditional or marginalized status. Instead, the present study looks at the use of a previously-validated and reliable survey instrument, the Modified Approaches and Study Skills Inventory (M-ASSIST),[137] to make predictions about students' course outcomes. The items from this instrument target students' study approaches, classifying them as deep or surface approaches. Combined with data collected on students' specific learning and study methods (e.g., attending lecture, reading the textbook), this research provides an imperfect but significant measurement of student outcomes. Such an instrument has the potential to provide instructors with the information needed to identify the distinct skills or approaches that at-risk students lack, rendering a more tailored approach to intervention possible.

The following section will provide a background on some of the current practices in approaching the attrition problem, as well as previous efforts that have been taken to predict student outcomes and define deep and surface learning. A description of the setting for this study and the guiding research questions and methods will follow. Results are separated by research question, and a discussion section addresses the ways that these key findings are situated in the current literature. We conclude with a few general takeaways and implications for practitioners, along with an acknowledgement of limitations and future points of interest.

Background

Placement, Interventions, and Equity

In the education literature, the term "placement," usually refers to the directing of students into a pre-requisite[138-142] or co-requisite course[143-145] course that is deemed commensurate to their level of preparedness. Such placements have produced mixed results in the literature. While an online preparatory course at UC-Davis benefited underprepared students,[142] a multi-year study of another preparatory chemistry course at Texas Tech University concluded that the remediation provided "little or no significant academic benefit."[138] "Intervention," on the other hand, typically refers to ancillary programs or activities within a course that aim to improve student outcomes with respect to specific course content (e.g. acids and bases[146]), skills (e.g. language comprehension[147]), or beliefs (e.g. growth mindset[148]). Benefits of early interventions in the classroom have been well-documented in first-year STEM courses.

The present study looks at students in the General Chemistry course sequence (GC1 and GC2) at Rutgers University, in which approximately one-quarter of the students earn grades of a D or F in the class (excluding students who withdraw). Students who do not perform well on the first exam in GC1 are strongly encouraged to switch into the Chemistry Preparatory (ChemPrep) course for the remainder of the semester. These students do not receive a "W" on their transcript for GC1 and they begin with a "clean slate" (grade-wise) in the new course. Mills et al. describe a similar system after finding a high correlation with first exam performance and course grades.[149] While ChemPrep has anecdotal accounts of success, it is not without limitations. Not all students' schedules can accommodate a mid-semester swap, which also places students at least one semester behind with few options for recovery. Summer coursework can prove impossible for students who do not live nearby, lack the financial means, or who must spend this time working or tending to family. Alternatively, waiting until the fall postpones enrollment in subsequent courses such as Organic Chemistry, potentially delaying graduation and proving a financial burden.

While placements ensure that students do not become overwhelmed by material they are unprepared for, the very act of placement is inherently inequitable to students with financial insecurity, disabilities, and who are part of marginalized communities. These students already face significant barriers when entering these academic spaces and leave at higher rates.[150] By identifying predictive factors of success, researchers and practitioners can work toward early, concurrent intervention where the goal is to retain students via a personalized approach, as opposed to placement.

Predicting Success

Many studies have quantified students' odds for success and persistence in higher education. In the STEM education literature, factors linked to student outcomes include SAT scores,[151-153] GPA,[113, 152, 154] demographics,[113, 152, 153, 155] and self-efficacy.[99] Content-based assessments such as the California Chemistry Diagnostic Exam[156] or the Toledo Chemistry Placement Exam[157] have used students incoming content knowledge to predict outcomes. Not only have these efforts provided valuable information about a student's likelihood of success in courses, but they have informed teaching practices and highlighted issues of equity in the classroom.

Another area of interest in terms of course outcomes is students' choice of study methods and the specific ways they employ these methods. In one investigation, Ye et al. used text messages to collect data on the types of study materials and frequency of use in a General Chemistry course.[158] In addition to linking study methods to outcomes, the authors found evidence that students changed their study methods over time, positing that recent exam content may have been the cause. In a second study by Ye et al., qualitative analysis suggested that the quality of studying was linked to at-risk students' course outcomes.[151] For example, several students reported studying with friends, but while some saw this as an opportunity to learn through teaching their peers ("deep approach"), another stated that they relied on their peers to help them or provide answers ("surface approach"). The current study uses some metrics to quantify the quality of studying and draws upon a similar deep/surface dichotomy, for the purpose of developing a predictive model of student success.

Deep and Surface Learning

The Approaches and Study Skills Inventory for Students (ASSIST) was developed by Tait et al. in 1997 and assesses students on their ideas about learning, study habits, and teaching preferences. classifying them as deep, strategic, or surface learners.[159, 160] A shortened, modified version of this instrument, the M-ASSIST, was constructed by Bunce et al, in 2017 and examined deep and surface study approaches of General Chemistry students at the United States Naval Academy.[137] The authors define deep learners as those who purposefully attempt to connect new knowledge to that which they already know using the underlying concepts. In contrast, surface learners approach new knowledge in an algorithmic fashion, looking predominantly at the surface features of a problem and relying on rote memorization. The results showed that student success was positively correlated with deep study approaches and negatively correlated to surface study approaches.

In the present study, an investigation of such deep and surface learning approaches is used to construct a predictive model for student outcomes in General Chemistry. Identifying at-risk students early in the course may facilitate intervention over placement, while knowledge gained about students' learning approaches and habits may prove useful to instructors in determining the type of intervention needed for different students.

Research Questions

The first goal for the present study was to determine if the results from the M-ASSIST study could be replicated with a new population. Specifically, the M-ASSIST was examined as a potential predictive tool to identify at-risk students early on in the course. Further relating these deep and surface study approaches to specific habits (e.g. reading the textbook) may provide tangible advice or intervention strategies for these students. The research questions (RQs) pertinent to this study are as follows:

- To what extent can students' deep and/or surface approach(es) to studying, combined with demographic information, predict student success in general chemistry at a large, diverse, research-intensive institution?
- How do students' study habits correlate with their deep and surface study approaches as measured by the M-ASSIST?

Setting

Population and Course Structure

The General Chemistry courses at Rutgers consist of large-enrollment lectures and weekly online, synchronous recitations that focus on problem-solving for topics covered during previous lectures. Weekly homework is provided online via an in-house program with a combination of static and dynamic content and students take three common-hour midterm exams, with both multiple-choice and open-ended components. The final exam consists of the most recent multiple-choice single-semester ACS exam plus five two-part open-ended questions. Teaching interns (TIs) hold supplemental instruction sessions, including workshops, office hours, and review session.

Table 5.1. Demographic Data for General Chemistry I (Fall 2018), N=1,455

Demographic Category	%	Demographic Category	%
Gender		**Race**	
Female	60.5%	South/East Asian	45.8%
Male	38.9%	White	29.3%
Non-Binary/Other	0.6%	Black/African-American	6.8%
Generation Status		Middle Eastern/North African	4.8%
First Generation College Student	27.4%	Native Hawaiian/Pacific Islander	0.6%
Major/Track*		Native American	0.3%
Life Sciences	63.1%	Two or More Races	5.8%
Physical Sciences	15.7%	**Ethnicity**	
Pharmacy	10.9%	Hispanic/Latino	12.4%
Social Science	6.2%	**Previous Chemistry Coursework**	
Engineering	3.0%	High School – None	1.1%
Other	1.1%	High School – 1 semester to 1 year	66.7%
Pre-Health Track†	83.6%		
Course Goals		High School – 2+ Years	31.2%
Earn an A	80.3%	College – None	85.1%
Earn a B	18.0%	College – 1 semester	11.2%
Earn a C/Pass	1.7%	College – 2+ semesters	3.6%

*Major/Career Track data is based on the Fall 2015 cohort, as data for the Fall 2018 was unavailable

†Students on the pre-health track may select any major(s)

Data Collection and Analysis

The Modified Approaches and Study Skills Inventory (M-ASSIST)

In this study, the M-ASSIST was issued to students online during the first (pretest) and last (post-test) weeks of the Fall 2018, Spring 2019, and Fall 2019 semesters using

Qualtrics. However, the remainder of this paper focuses on the post-test results of the M-ASSIST since the bulk of students' grades are determined in the final few weeks of the semester

The decision to administer the M-ASSIST was driven by practicality of implementation and its content agnosticism. The brevity and ease of scoring made it an attractive model to use in a class of 1,500+ students. Further, the purpose was not to assess chemistry knowledge and the researchers believe that the items on the M-ASSIST can be reasonably answered by students regardless of their chemistry background. It contains only twelve items of one sentence each, with six items contributing to the deep scale and six items to the surface scale, for which students are asked to note their level of agreement on a five-point Likert scale, specifically in the context of General Chemistry. Data was analyzed in R and SPSS (Version 26). Deep and surface scores are calculated by taking the average score of each subscale. Students who did not answer more than one item on both subscales were excluded from the analysis. The full M-ASSIST can be found in the original paper by Bunce et al.[137]

The Student Individuality Survey (SIS)

A second survey, the Student Individuality Survey (SIS), was developed in-house and consists of two portions: The first asks students to provide demographic data, as well as course goals, and the extent of their previous high school and college chemistry coursework, (Table 5.1). The second part of the survey includes a series of questions about students' learning and studying habits in the context of General Chemistry. The SIS was administered to students online alongside the M-ASSIST. A copy of this instrument can be found in the Supporting Information. SIS data was analyzed using SPSS Version 26.

Regression Analysis

Logistic Regression was performed in the statistical program R using student outcomes as the dependent variable and various combinations of students' deep scores, surface scores, and demographics as the predictor variables. To determine the best model, the proposed models were compared using the Akaike's An Information Criterion (AIC), a multi-model inference technique.[161] In brief, the AIC value estimates the relative strength of each model within a set based on parsimony and goodness of fit. The smaller the AIC number within a set, the better the combination of fit and parsimony.

The ΔAIC is calculated by identifying the model with the smallest AIC and computing the absolute value of the difference between that model and all other models.[162] Only models in which all predictor variables (e.g. gender) have at least one significant individual factor component (e.g. female) are considered. The model with the smallest ΔAIC, which also meets this significance criterion, is selected. Further details on the statistical analyses and sample R commands are provided in the Supporting Information.

IRB Approval and Consent Procedures

All methods and procedures were granted IRB approval from the institution, under IRB protocol 15-814M, with annual renewal.

Results

RQ1, Part I: Defining Success

Students' study skill scores were measured on the deep and surface subscales and separated according to their final grade in the class. Figure 5.1 shows the distribution of average deep and surface scores for each letter group in the fall and spring semesters. Note that the surface score appears to be more sensitive than the deep score. This is consistent with the findings of by Bunce and colleagues.[137]

Gellene and Bentley suggest that multivariable prediction models perform best when the student outcome is binary.[138] In lieu of letter grades, student outcomes were labeled "successful" (S) or "unsuccessful" (U), with success defined as earning a grade of B or higher. The decision to use this cut-off stemmed from a few considerations. First, in both semesters, over 98% of the students selected a grade of "A" or "B" (Table 5.1) as their goal. Most convincingly, however, were the trends in grades from GC1 to GC2, illustrated in Figure 5.2. Of the students who earned an A in GC1, 94.3% of them earned a grade of A or B/B+ in GC2. Just over half of the students earning a B/B+ in GC1 earned a grade of A or B/B+ in GC2. Comparatively, not a single student from this cohort received an A in GC II following a grade of C/C+ in GC1, and only 9.6% of them earned a B/B+. This sharp contrast between the two groups lends support to the use of "B or better" as a demarcation line for success.

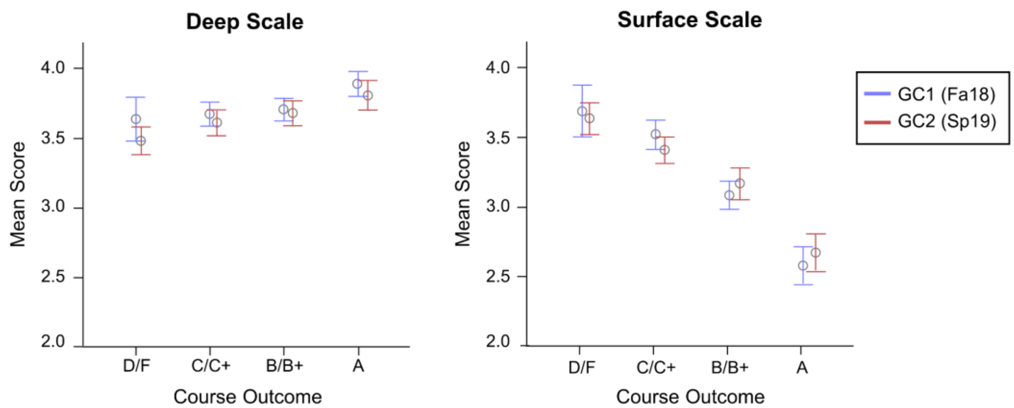
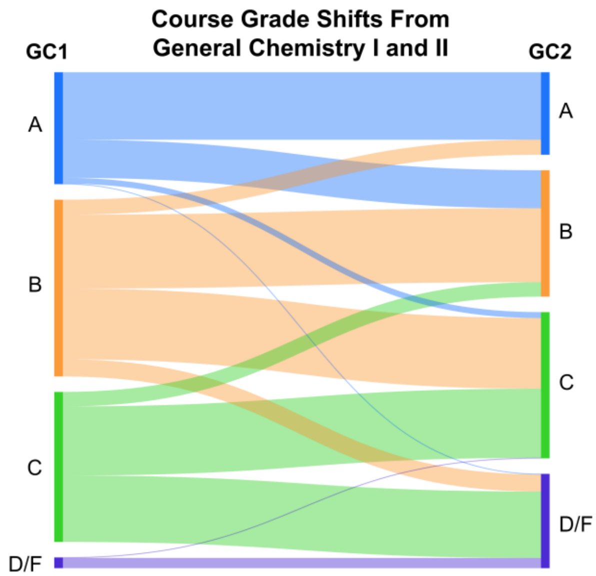


Figure 5.1. Average deep and surface scores from the M-ASSIST[1] were calculated according to the four grade groups for each semester and plotted on the graphs. Error bars represent the 95% confidence intervals.



		Grade in GC1 (Fa18)			
		A	**B**	**C**	**D/F**
Grade in GC2 (Sp19)	**A**	60.3%	8.5%	0.0%	0.0%
	B	34.0%	41.8%	9.6%	0.0%
	C	5.3%	40.0%	46.1%	5.0%
	D/F	0.4%	9.7%	44.3%	95.0%
	SUM	100.0%	100.0%	100.0%	100.0%

Figure 5.2. (top) A Sankey diagram showing the flow of grades students earned in GC1(left) and then in GC2 (right). The width of the bands is proportional to the number of students represented. This data only shows students who completed GC1 in Fall 2018 and transitioned into and completed GC2 in Spring 2019 (N=839). A full set of outcomes can be found in the Supporting Information (Table 5.S1). For clarity, the percentages representing each band are provided in the grid (bottom) and are calculated as a percentage of students earning a given letter grade in GC1.

RQ1, Part II: Calculating Study Skills Scores

Figure 5.3 provides a breakdown of responses for each item on the M-ASSIST by outcome group for the Fall 2018 semester. An independent t-test is used to investigate any differences between the two groups and an effect size is calculated using Cohen's *d*. As a whole, there are greater differences between the two groups on the surface scale compared to the deep scale for both semesters, reflecting the findings from Figure 5.1.

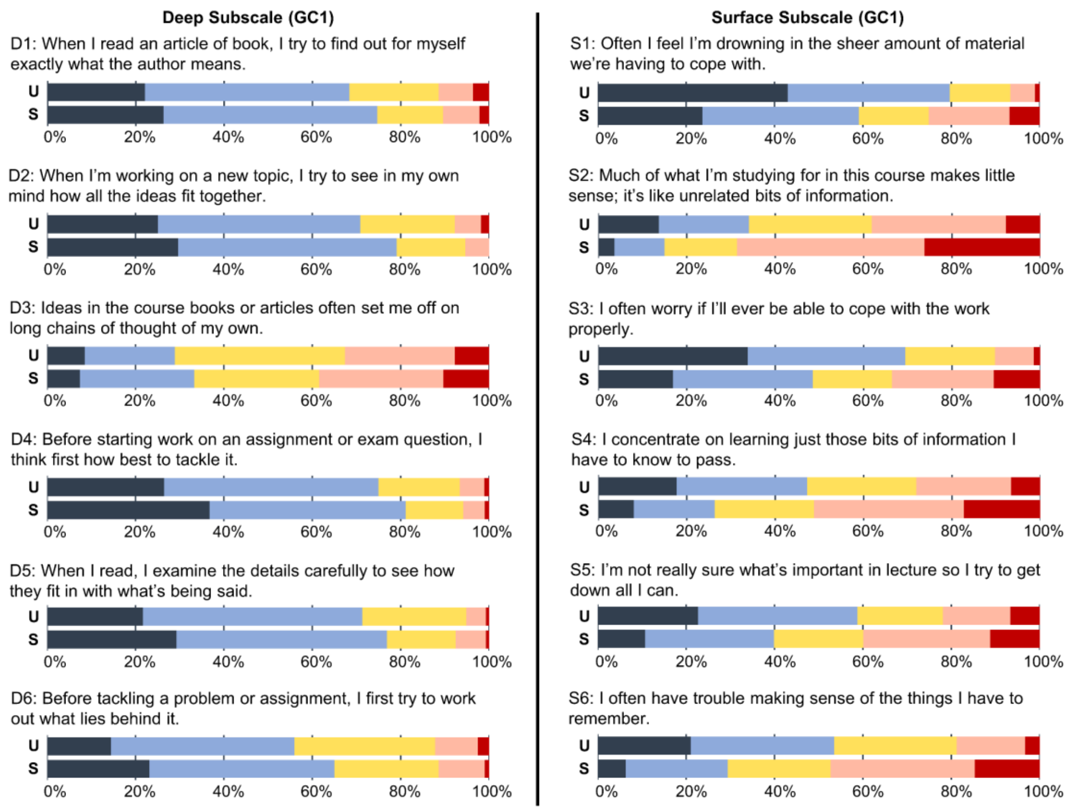


Figure 5.3. Responses from successful (S) and unsuccessful (U) students on the twelve items from the M-ASSIST for the Fall 2018 GC1 course. Responses of "strongly agree" are represented by dark blue (left-side of scale) and responses of "strongly disagree" are in dark red (right-side of scale). N_S = 411; N_U = 273. Responses for the Spring 2019 semester can be found in the Supporting Information.

For the fall term, analysis of the individual items yielded significant differences with moderate effect sizes for all items on the surface scale (Table 5.2). Items S2 and S6 both target sense-making and have the largest effect size. While the deep scale contains three items that suggest significant differences between the U/S groups, the data is underpowered to make definitive claims. The spring semester (Table 5.S2, Supporting Information) followed a similar trend with respect to the surface scale; however, four items on the deep subscale were significantly different and achieved a statistical power of $\beta \geq 0.80$. Still, the effect sizes were considerably smaller compared to those of the surface scale.

Table 5.2. Differences Per M-ASSIST Item for Successful and Unsuccessful Students* (Fall 2018)

	Deep (D)			Surface (S)		
Item	Sig.	Effect Size	Power	Sig.	Effect Size	Power
1	0.103	NS	NS	0.000	0.576	≥0.999
2	0.016	0.193	0.695	0.000	0.706	≥0.999
3	0.486	NS	NS	0.000	0.603	≥0.999
4	0.014	0.192	0.691	0.000	0.547	≥0.999
5	0.130	NS	NS	0.000	0.448	≥0.999
6	0.009	0.206	0.747	0.000	0.701	≥0.999

*N_S=411; N_U=273; “NS” is “not significant”

Heatmaps were created by plotting each student according to their average deep and surface scores (Figure 5.4). Data points are colored on a gradient according to the proportion of successful students at that point. Areas with a higher proportion are coded in blue, while those with a lower proportion are coded in red. Whole-class average deep and surface scores form the four quadrants. In both semesters, Quadrant 1 (top-right) contains the greatest density of blue (successful) data points. These are the students with high deep scores and low surface scores. Students in Quadrant 4 (bottom-right) did not have many successful outcomes, despite having above-average deep scores, illustrating the differences in sensitivity between the deep and surface scales seen previously in Figure 5.1. Table 5.3 lists the average fraction of successful students per quadrant to supplement the visual representations of the data. Note that, in both semesters, the quadrants with below-average surface scores had the largest fractions of successful students.

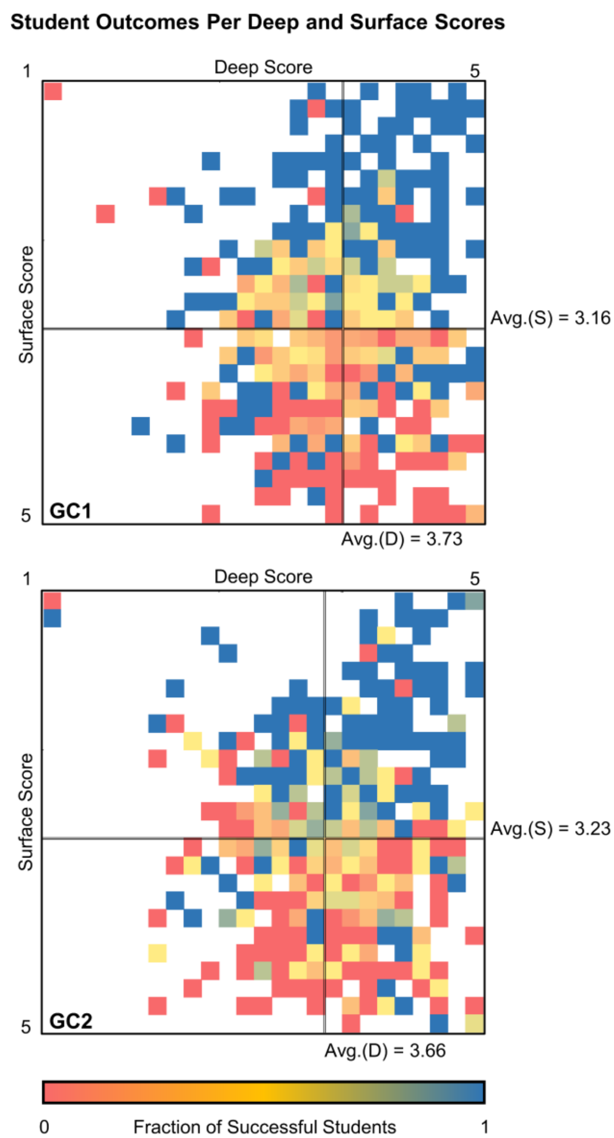


Figure 5.4. Heatmaps for the GC1 (top, *N*=653) and GC2 (bottom, *N*=697) courses were created by calculating the proportion of students that were successful at each possible combination of average deep (x-axis) and surface scores (y-axis). Dark blue points represent a fraction of success = 1, whereas red represents a fraction of success = 0. White spaces indicate that no student had that combination of scores. Quadrants are formed using the overall average deep and surface scores and are numbered 1-4, starting in the top-right quadrant and proceeding counter-clockwise.

Table 5.3. Fraction of Successful Students per Quadrant

Quadrant	Deep Scale	Surface Scale	Fraction of Success	
			GC1	GC2
1	High	Low	0.85	0.78
2	Low	Low	0.67	0.49
3	Low	High	0.43	0.38
4	High	High	0.41	0.35

RQ1, Part III. Modeling and Predicting Success

Logistic regression was carried out on the binary outcome data (successful versus unsuccessful) as a function of various combinations of students' surface scores, deep scores, and demographics (first generation status, gender, and race/ethnicity). Due to sample size, the categories of race and ethnicity were combined, as has been common practice in previous studies.[152, 155, 163] Table 5.4 provides an overview of the proposed models along with the AIC and ΔAIC values.

Table 5.4. Regression Models to Predict Student Outcomes in General Chemistry

Model	Predictor Variables	AIC	ΔAIC
General Chemistry I – Fall 2018			
Fa0	deep + surface	811.0	76.4
Fa1	deep + surface + first generation	764.8	30.2
Fa2	deep + surface + first generation + gender	757.1	22.4
Fa3	deep + surface + first generation + gender + race/ethnicity	734.7	0.0
Fa4	deep + surface + gender + race/ethnicity	751.5	16.8
Fa5	deep + surface + race/ethnicity	760.4	25.7
Fa6	deep + surface + first generation + race/ethnicity	743.5	8.9
General Chemistry II – Spring 2019			
Sp0	deep + surface	908.7	115.9
Sp1	deep + surface + first generation	821.1	28.3
Sp2	deep + surface + first generation + gender	816.6	23.8
Sp3	deep + surface + first generation + gender + race/ethnicity	792.8	0.0
Sp4	deep + surface + gender + race/ethnicity	804.0	11.2
Sp5	deep + surface + race/ethnicity	808.4	15.6
Sp6	deep + surface + first generation + race/ethnicity	796.8	4.0

Table 5.5 provides the regression parameters associated with each model listed in Table 5.4. Each of the β_n values are log-odds parameters. The categorical variables produce parameters whose log-odds are relative to one of the component factors. Each factor is assigned a label of 1 through m, where m is the total number of factors within that categorical variable. Using the criteria described previously in this paper, the best model selected for each semester are as follows:

$$Outcome = \beta_0 + \beta_1 Deep + \beta_2 Surface + \beta_3 FirstGen + \boldsymbol{\beta_4} Race/Ethnicity \quad (1)$$

$$Outcome = \beta_0 + \beta_1 Deep + \beta_2 Surface + \boldsymbol{\beta_4} Race/Ethnicity \quad (2)$$

Table 5.5. Regression Model Parameters to Predict Student Outcomes in General Chemistry

Model	Log-Odds Parameters (βn)							
	Intercept	Deep	Surface	FirstGen2	Gender2	RaceEth2	RaceEth3	RaceEth4
General Chemistry I – Fall 2018								
Fa0	2.364***	0.388**	-1.042***					
Fa1	2.582***	0.414**	-1.071***	-0.649**				
Fa2	2.345***	0.441**	-1.067***	-0.658**	0.324			
Fa3	2.124**	0.429**	-1.073***	-0.638**	0.358	-0.250	0.498*	0.402
Fa4	1.848**	0.430**	-1.051***		0.346	-0.366	0.542**	0.440
Fa5	2.112***	0.404**	-1.054***			-0.388	0.500*	0.390
Fa6	2.403***	0.400**	-1.076***	-0.637**		-0.271	0.459*	0.355
General Chemistry II – Spring 2019								
Sp0	1.136*	0.516***	-0.920***					
Sp1	1.699**	0.429**	-0.943***	-0.459*				
Sp2	1.470*	0.452***	-0.931***	-0.441*	0.265			
Sp3	1.612*	0.454**	-0.971***	-0.392	0.271	-0.787	0.090	-0.190
Sp4	1.366*	0.499***	-0.973***		0.263	-0.926*	0.086	-0.202
Sp5	1.602**	0.479***	-0.987***			-0.980*	0.065	-0.232
Sp6	1.851**	0.434**	-0.984***	-0.402		-0.829*	0.070	-0.220

*p≤0.05; **p≤0.01; ***p≤0.001

FirstGen2: holds first generation college status; Gender2: Male; RaceEth2: Hispanic/Latinx; RaceEth3: Asian; RaceEth4: Black or African-American

Only the predictor variables with significant regression parameters are included in the best models. The bolded β_4 terms refer to a set of parameters related to the Race/Ethnicity variable. In the case of Model Fa6 (Equation 1), the significant factor component for the Race/Ethnicity categorical variable is that for Asian (RaceEth3, Table 5.5). For Model Sp5 (Equation 2), the significant factor component within the same variable is that for Hispanic/Latinx (RaceEth2, Table 5.5).

To evaluate the predictive capabilities of these two models, outcome probabilities are computed by plugging in students' data into the selected models. These probabilities are translated into predicted outcomes using the following decision boundary: a probability of ≥0.5 was assigned "1" (successful) while a probability of <0.5 was assigned "0" (unsuccessful). Students' predicted outcomes were then compared to their actual outcomes in the course (Table 5.6).

Table 5.6. Predictive Capabilities of Regression Models

Value	GC1 - Fall 2018		GC2 - Spring 2019		GC1 - Fall 2019
Model Used	Fa6*	Sp5	Sp5*	Fa6	Fa6
N_{Total}	643	649	652	644	485
N_U (actual)	248	252	312	307	203
N_S (actual)	395	397	340	337	282
Specificity[a]	80.0%	70.3%	66.5%	81.0%	86.9%
Sensitivity[b]	48.4%	61.1%	62.5%	44.6%	48.8%
% Pos. Predictive Value[c]	71.2%	74.0%	65.9%	61.6%	70.2%
% Neg. Predictive Value[d]	60.3%	56.6%	63.1%	68.2%	72.8%
% Predicted Overall	67.8%	66.7%	64.6%	63.7%	70.9%

[a] % of successful outcomes correctly predicted by model
[b] % of unsuccessful outcomes correctly predicted by model
[c] % of successful predictions that were correct
[d] % of unsuccessful predictions that were correct
*Model selected based on ΔAIC

In the Fall 2018 semester, Model Fa6 correctly predicts an unsuccessful outcome in the course slightly less than fifty percent of the time, but predicts successful outcomes slightly more than eighty percent of the time. This remains true even when the same model is tested with a different cohort in Fall 2019. GC2 Model Sp5 correctly predicts desirable and undesirable outcomes nearly two-thirds of the time. Results from testing the two models on the alternate semesters (i.e., Sp5 model used on GC1 data, Fa6 model used on GC2 data) are also provided in Table 5.6. In both cases, the use of these alternate models provides lower overall prediction rates, supporting the use of two different models, Fa6 and Sp5, for their respective semesters.

RQ2: Study Skills and Academic Habits

Students' lecture habits were correlated with their average deep and surface scores using a Spearman Rank Order Correlation (Table 5.7). In both GC1 and GC2, average deep scores are significantly correlated with all five items listed under learning habits, though the correlation coefficients were small in magnitude. The item "focus in lecture" has the largest correlation with the deep score in both semesters and the only significant correlation with the surface score, which is negative.

Table 5.7. Spearman Correlations of Study Skills and Learning Habits

"*How frequently do you do the following?*" (5-pt Likert Scale)	GC1 - Fall 2018		GC2 - Spring 2019	
	Deep	Surface	Deep	Surface
Attend lecture	0.094*	-0.035	0.155***	-0.063
Prepare before lecture	0.178***	0.018	0.149***	0.016
Take notes during lecture	0.122***	0.014	0.104**	-0.027
Pay attention in lecture	0.208***	-0.154***	0.208***	-0.147***
Take notes while reading textbook/lecture notes	0.191***	0.048	0.169***	0.009

*p≤0.05; **p≤0.01; ***p≤0.001

Spearman correlations were also calculated for students' deep and surface study skills with their general approaches and beliefs towards studying (Table 5.8). Overall, this section encompasses the largest correlation coefficients. Satisfaction with study habits is positively correlated with the deep score in both semesters and negatively correlated with the surface score, suggesting that students do have some awareness of their academic progress in the class. However, results on the second item suggest that students with higher surface scores may not know how to improve their study habits.

On the SIS, cramming is defined as "mass studying in the last day or two before an exam, rather than spread out." The frequency of cramming for exams is positively correlated with the surface score, and negatively correlated with the deep score for both semesters. Still, when those who indicate at least some tendency to cram are asked about the effectiveness of their cramming, no clear trend could be identified except for a small negative correlation with the spring's surface score.

The final item in this section asks students whether or not they felt they had to memorize a significant amount of material in the class. Agreement with this item resulted in a low negative correlation with the deep score and a moderate positive correlation with the surface score. Despite the different content material presented in GC1 and GC2, these results were consistent in both semesters and align with that which would be expected from the M-ASSIST.

Table 5.8. Spearman Correlations of Study Skills and Beliefs About Habits

Frequency/Agreement with the following:	GC1 - Fall 2018		GC2 - Spring 2019	
	Deep	Surface	Deep	Surface
I am satisfied with my study habits (3pt-Likert scale)	0.180***	-0.327***	0.112**	-0.335***
I know how to improve my study habits‡ (T/F)	0.078	-0.315***	0.112**	-0.159***
How often do you cram before exams? (5-pt Likert scale)	-0.176***	0.400***	-0.137***	0.246***
Do you believe cramming works well for you?† (3pt Likert scale)	-0.003	-0.073	-0.015	-0.143***
I find myself having to memorize a significant amount of material in this class (T/F)	-0.243***	0.454***	-0.179***	0.391***

*p≤0.05; **p≤0.01; ***p≤0.001

‡This item was only available for those who selected “Somewhat Satisfied” or “Not Satisfied” with the previous item, “I am satisfied with my study habits”

†This item was only available for those who did not select “Never” to the previous item, “How often do you cram before exams?”

Finally, students were provided with a set of eight study methods and told to select as many methods as they actually found helpful during the semester. The preferred study methods are neither consistent between semesters, nor were any of the correlation coefficients sufficiently large (Table 5.9). The only study methods that produced significant results in both GC1 and GC2 were reading the textbook (positively correlated with the deep score) and watching videos online (positively correlated with the surface score). Online videos are not a component of the course, and thus refer to any videos from third parties that students sought independently.

Table 5.9. Spearman Correlations of Study Skills and Study Habits

How helpful do you find the following when studying? (3-pt Likert Scale)	GC1 - Fall 2018		GC2 - Spring 2019	
	Deep	Surface	Deep	Surface
Reading the textbook	0.080*	-0.027	0.151***	0.020
Reading the instructor's notes	0.007	-0.146***	0.042	-0.072
Reading another instructor's notes	-0.049	0.081*	-0.040	0.072
Watching videos online	0.033	0.219***	-0.027	0.132***
Writing own notes	0.034	-0.037	0.067	-0.039
Doing practice problems from the textbook	0.149***	-0.118**	0.056	0.001
Doing practice problems from outside of the textbook	-0.005	-0.013	0.024	-0.038
Re-doing the homework	0.092*	-0.053	0.042	0.003

*p≤0.05; **p≤0.01; ***p≤0.001

One possible explanation for the low predictability of at-risk (predicted-unsuccessful students) in the fall is that their study methods might vary. These students were divided into two groups: at-risk, successful (N=76) and at-risk, unsuccessful (N=117). The percentage of students in these two groups who utilize each of the study methods was calculated and compared using a Chi-square test (Table 5.10). For GC1 in Fall 2018, watching videos online is the only study method that shows a significant difference between the successful and unsuccessful students that were initially deemed at-risk.

Table 5.10. Study Methods of At-Risk Students By Course Outcomes (Fall 2018)

Study Method	At-Risk (S) % Use	At-Risk (U) % Use	Chi-square, X^2	Sig.
Reading the textbook	52.5	59.5	0.983	-
Reading the instructor's notes	78.8	77.0	0.088	-
Reading another instructor's notes	62.5	57.1	0.582	-
Watching videos online	57.5	84.1	17.9	$p \leq 0.001$
Writing own notes	65.0	61.1	0.316	-
Doing practice problems from the textbook	56.3	56.4	0.000	-
Doing practice problems from outside of the textbook	60.0	60.3	0.002	-
Re-doing the homework	32.5	42.1	1.89	-

N_S=76; N_U=117

Discussion

Deep and Surface Subscales

While students' surface scores on the M-ASSIST exhibit clear differences between the achievement groups, the deep scale appears to be less sensitive overall. These findings mimic those reported in the original M-ASSIST study by Bunce and colleagues,[137] which found that the surface scale could readily differentiate between the three grade groups (A/B, C, and D/F), while the deep scale did so to a lesser extent.

The relationship between students' deep and surface scores with their course outcomes are readily visualized by the heatmaps in Figure 5.4. Notably, the quadrants with below-average surface scores contain the largest fraction of students earning a B or better in the course. Specifically, students with below-average surface scores and above-average deep scores seem to fare the best. Interestingly, however, the same trend is not apparent with students who have higher surface scores. That is, the differences in the fractions of success between Quadrants 3 and 4 are less apparent than the differences between Quadrants 1 and 2. In fact, students in Quadrant 4 (high surface/high deep) as a whole had lower proportions of success than students than students in Quadrant 3 (high surface/low deep), for both semesters. While the deep scale was found to be less sensitive than the surface scale, that students in Quadrant 4 had lower proportions of success was unexpected.

Previous work on study approaches suggests that students within this quadrant are not homogenous in terms of their beliefs and approaches to studying for coursework. Entwistle et al. used a cluster analysis to characterize student responses to the Approaches to Studying Inventory (ASI), the predecessor to the M-ASSIST.[164] While most clusters appeared to be typical (i.e., deep and surface scores were inversely related), one cluster reported unusually high deep scores with high surface scores. This particular cluster was the second-lowest in academic performance (out of six) and was not far behind the lowest-performing cluster.

Entwistle describes these high-deep/high-surface students as "disorganised in their studying, highly anxious and with confusion in…their intention to seek meaning and declared interest in the ideas in the course, on the one hand, and their…weak levels of understanding on the other."[164] He suggests a differentiation among the lower-performing students, specifically between the students with genuine surface approaches and those who are likely deep learners but who do not know how to properly utilize those approaches, (and fall back on surface approaches instead). This dissonance is recognized in similar studies,[165-167] and is consistent with what is known about metacognitive skills and course performance. Students who effectively utilize metacognitive strategies, such as evaluating their understanding and monitoring their study habits, tend to perform better academically.[110, 151, 168-170] Some surface learners may perform poorly simply due to their surface approaches to learning (failing to evaluate their understanding). Others may acknowledge that a deep approach is more effective, but are either unsure as to how to execute that approach successfully (failing to monitor their study habits).

Modeling Success

In each of the regression models for both the fall and spring semesters, the deep and surface scores emerged as the strongest predictors among the independent variables (Table 5.5). When incorporating the demographic data, identifying as Hispanic (GC2) and/or first-generation (GC1) was found to have a negative impact on outcomes, while identifying as Asian (GC1) was found to have a positive impact. These findings are consistent with current literature[150, 163, 171] but still serve as an important reminder of the role of student identity in this research.

Overall, both the Fall 2018 and Spring 2019 models were able to correctly predict student outcomes roughly two-thirds of the time (Table 5.6). Gellene and Bentley estimate that even with a binary outcome, the predictive accuracy of multivariable models reaches a maximum around 70-80% due to "intangible" quantities such as individual motivation.[138] The Fall 2018 GC1 model exhibited a large disparity in its specificity versus sensitivity (80.0% versus 48.4%, respectively), which was repeated when the model was applied to data from the Fall 2019 cohort. This sensitivity/specificity gap has been previously observed by other researchers, though a definitive explanation has not been established.[149, 172] Still, the consistency between the two fall semesters was encouraging. The model applied to the GC2 course was more equitable in its predictions, correctly identifying the outcomes of successful students 66.5% of the time, and unsuccessful students at 62.5% of the time. It is possible that the students in GC2 are a more homogeneous cohort due to a "filter effect" resulting from GC1-to-GC2 attrition. The degree to which such homogeneity accounts for the fidelity of the predictive models warrants further investigation.

Study Methods and Metacognition

The second research question focused on the habits and study methods that students report using in the class. Generally, favorable lecture habits (e.g. preparing ahead of time) were positively correlated with the deep score (Table 5.7), while crammed studying and memorization of content were positively correlated with the surface score (Table 5.8). These findings contribute to the validity of the M-ASSIST.

Examination of the specific study methods that students report using in class indicate that deep and surface learners draw upon many of the same resources (Table 5.9). However, watching videos emerged as a practice moderately correlated with the surface score in both GC1 and GC2. Students who were deemed at risk and were ultimately unsuccessful were significantly more likely to report watching these videos compared to the at-risk, successful group (Table 5.10). Online media continues to mold the educational landscape and has offered many benefits to learning.[173] However, students who lack effective metacognitive skills may be more prone to passive learning at best and mis-calibrated confidence at worst.[174-176] Students with high surface scores, and are thus predicted to be at-risk, may be more prone to using these unhelpful practices while engaging with online videos. This is particularly true if the online videos do not have built-in features to encourage students to reflect or self-assess on content related to the subject matter.

Conclusions

Drawing on one full year of General Chemistry at a large R1 university, a logistic regression model containing predictor variables of deep scores, surface scores, and demographic data has an overall prediction accuracy between 65-70%. Notably, the surface scores are the strongest predictors of success. It is a promising finding that the deep and surface scales' sensitivities were consistent with those found by Bunce and colleagues,[137] despite the fact that the present study's cohorts were quite different.

Although numerous placement tests have been previously described in detail, the M-ASSIST does have some unique benefits. First, the M-ASSIST consists of only 12 items, can easily be administered online, and typically takes less than 10 minutes to complete. Secondly, the M-ASSIST does not require any previous chemistry, math, or other STEM content knowledge. Lastly, the M-ASSIST can be quickly scored by instructors using any type of data analysis software or spreadsheet program and can provide actionable feedback for students if serving as an advisory tool.

It was unfortunately timely that this study coincided in part with the peak of the SARS-CoV-2 pandemic. Although not the intention, these circumstances serve as a reminder of how important it is for students to develop effective, independent study methods and approaches. General Chemistry is typically taken by students in their first year of college, while they are adjusting to a new setting, new responsibilities, and new freedoms. Compounded with poor metacognitive skills and an unlimited amount of resources at their disposal, some students may see these introductory courses as an obstacle to overcome, rather than as a stepping-stone towards their goals.

Implications for Instruction

The results from this study have precipitated three main implications. The first is that deep and surface learning approaches, as measured by the M-ASSIST, do not necessarily exist on a single spectrum, and thus students' placement on the surface scale, for example, may not be related to their placement on the deep scale. This suggests that a one-size-fits-all solution may not be suitable. For example, while studies have reported positive outcomes following in-class interventions on metacognitive strategies,[135, 177] one study found that high-achieving students may actually have adverse reactions to this type of intervention.[178] Instead, a prediction model such as the M-ASSIST may be a quick and useful tool to test and ultimately identify the best intervention for different students.

Secondly, results suggest that successful and unsuccessful students in this cohort do not appear to use drastically different study methods from one another. This serves as a reminder of the language gap between students and instructors, which can be succinctly summarized by Cook and collaborators:[135]

> …when students learn about Bloom's taxonomy, which almost none of them have seen before, they understand what faculty members mean by higher-order thinking. If students have never been explicitly taught that there is more to learning than memorization, they have no way of knowing how to develop higher-order thinking skills.

The authors here argue that vague phrases like "higher-order thinking" are not helpful for students who do not know how to apply these ideas in a tangible way. Analogously, one-dimensional or cliched study advice like "don't cram" or "read the textbook" not only make assumptions about an individual's prior knowledge about learning, but also ignores factors that might place them at risk. Instead, students in need of studying assistance should be guided in developing specific, actionable measures that they can reasonably implement. Instructors should avoid vague advice and be cognizant of the different ways that students utilize a given study method, as some may result in unproductive or deleterious outcomes.

Finally, one notable finding was that for at-risk, unsuccessful students, a higher frequency of studying via online videos is reported. There is no dearth of best practices literature on the use of videos education, such as the use of guiding questions or interspersed polling.[179-182] However, in the case of third-party videos that students seek independently, instructors should take time to educate (and remind) students of how to properly use these videos and monitor their understanding, emphasizing the pitfalls of passive learning or false confidence.

Future Directions and Limitations

This paper describes the first use of the M-ASSIST as a means for predicting student success in General Chemistry. The majority of students in this cohort were life-science majors with an interest in health professional careers. Further work could investigate how these study skills may differ amongst engineers, chemistry majors, and a variety of other student cohorts at different types of institutions (e.g. small liberal arts colleges, minority serving institutions, and regional comprehensive colleges and universities).

Further, there were no clear indications as to why the surface scale was more sensitive in predicting student outcomes although differences in students' metacognitive skills may be implicated. Likewise, students across the spectra of study skills and outcomes generally reported using similar study methods on their own. The next step may be to investigate the ways that students actually engage with these resources. Modifications to the SIS might help to move past the "what," into the "how" and would be better informed by qualitative data, such as interviews or focus groups. Such work could also increase the degree to which we can move students away from relying on surface-level strategies to approach their coursework and toward more deep, meaningful, and research informed methods.

Supporting Information for Chapter 5

Logistic Regression Analysis

Logistic regression fits a logistic function to a set of data in which the outcome variable is binary (0 or 1) and the predictor variables are continuous, categorical, or ordinal in nature. Deep and surface scores were each treated as continuous predictor variables in accordance with literature precedent[137] in the logistic regression models. First generation college student status, gender, and race/ethnicity were all treated as categorical predictor variables.

The parameters associated with each of these predictor variables are log-odds values. Upon exponentiation, the contribution of each predictor variable to the odds of success is obtained. However, of greatest interest in this study is the student's probability of success. This value is obtained by transforming the results of the logistic regression as follows:

$$Pr = \frac{1}{1+e^{-(\sum_{i=0}^{n}\beta_i x_i)}} \qquad (1)$$

Where Pr, β_i and x_i are the probability of success (a value ranging between 0 and 1), ith regression parameters, and predictor variables, respectively.

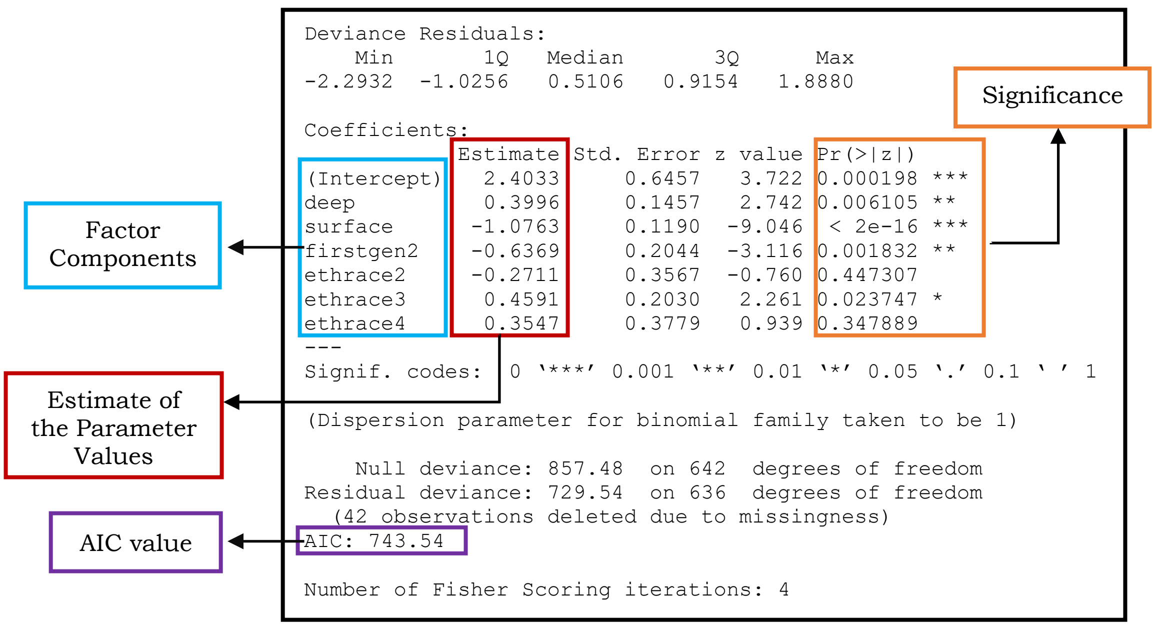
Sample R Command and Output for Logistic Regression

Below is a sample command for running a logistic regression in the statistical program R.[2] This command was used to run a logistic regression for Model 6 of General Chemistry I in the Fall of 2018 (i.e. Model Fa6):

```
Call:
glm(formula = Outcome ~ deep + surface + firstgen + ethrace, family =
binomial(link = "logit"),
    data = Outcomes_and_Demographics_161_F18)
```

Dependent variable: Outcome
Predictor variables: deep, surface, firstgen, ethrace
Filename: Outcomes_and_Demographics_161_F18

The output of this command is given as:



The factor components are the individual labels within an ordinal or categorical predictor variable. For example, ethrace3 (Asian) is a factor component of the categorical predictor variable ethrace (Ethnicity/Race). Estimates of the parameter values are the individual β_n values that are used in the regression model to calculate the outcome probability and generally represent the signed contribution of each variable to the outcome. The final column provides the significance of each variable. R also provides the AIC value near the bottom of the output.

Course Outcomes Data

The grade distributions in Table 5.S1 include all students who completed General Chemistry I and II in the Fall 2018 and Spring 2019 semesters, respectively, and provide context for the Sankey flow diagram in Figure 5.2 of the main text. Students who earn an “F” in General Chemistry I are prohibited from taking General Chemistry II without re-taking the course, and only in rare, case-by-case circumstances are students who earn a “D” in General Chemistry I allowed to continue to enroll in General Chemistry II without a re-take. For this reason, students who earned a D/F in General Chemistry I are underrepresented in Figure 5.2.

Table 5.S1. Grade Distributions* in General Chemistry by Semester

	GC1 (Fall 2018)		GC2 (Spring 2019)	
Grade	N	(%)	N	(%)
A	222	17.9%	192	17.3%
B+/B	364	29.4%	282	25.4%
C+/C	373	30.1%	340	30.6%
D/F	280	22.6%	297	26.7%
TOTAL	1,239	100%	1,111	100%

*These numbers do not include students who dropped out of the course.

M-ASSIST Student Responses – GC2, Spring 2019

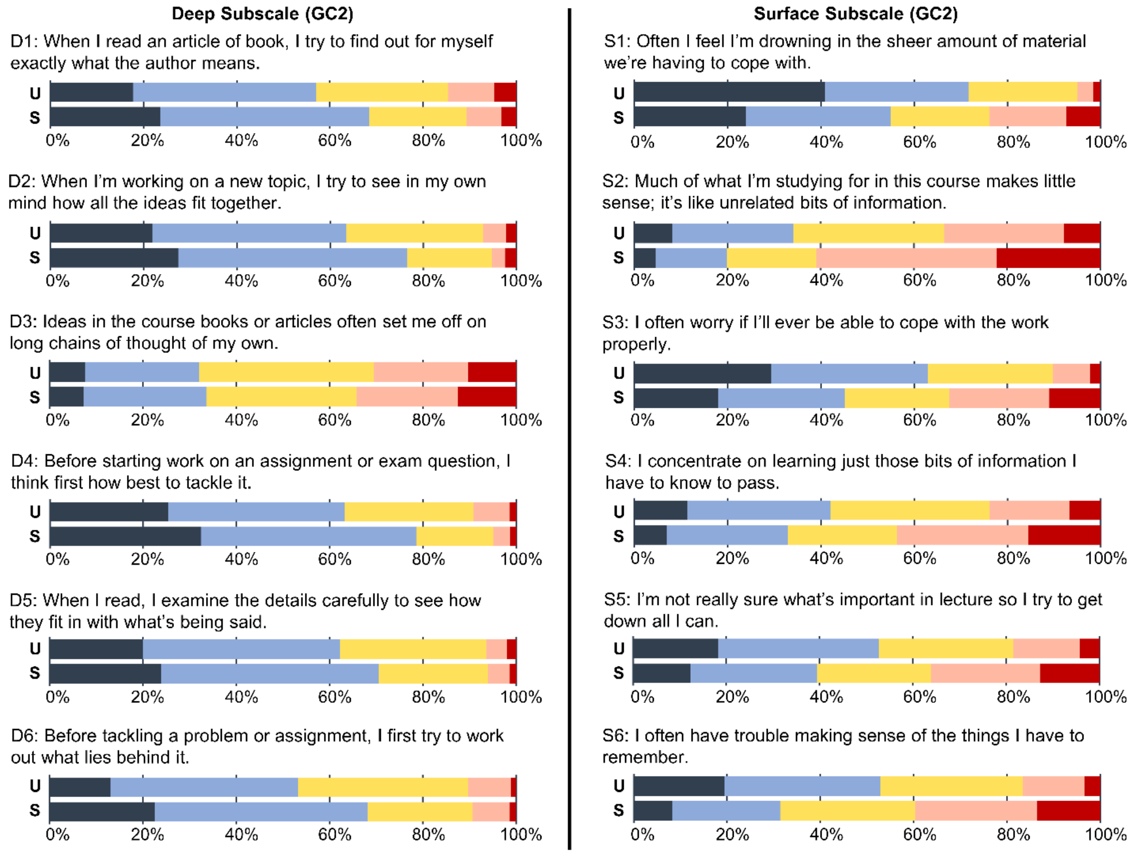


Figure 5.S1. Responses from successful (S) and unsuccessful (U) students on the twelve items from the M-ASSIST[1] for the Spring 2019 GC2 course. Responses of “strongly agree” are represented by dark blue (left-side of scale) and responses of “strongly disagree” are in dark red (right-side of scale). N_S = 364; N_U = 361.

M-ASSIST Item Analysis – GC2, Spring 2019

Table 5.S2 lists the outcomes of a t-test in GC2 when comparing successful and unsuccessful students on each M-ASSIST item.[1] With the exception of Items 3 and 5 on the Deep Scale, all items were found to have a significant difference. However, the effect sizes of the Surface Scale are lower overall compared to the Fall 2018 cohort (Table 5.2).

Table 5.S2. Differences Per M-ASSIST Item for Successful and Unsuccessful Students* (Spring 2019)

	Deep (D)			Surface (S)		
Item	Sig.	Effect Size	Power	Sig.	Effect Size	Power
1	0.003	0.220	0.841	0.000	0.531	≥0.999
2	0.003	0.220	0.840	0.000	0.539	≥0.999
3	0.590	NS	NS	0.000	0.524	≥0.999
4	0.000	0.289	0.972	0.000	0.376	≥0.999
5	0.046	0.149	0.515	0.000	0.394	≥0.999
6	0.000	0.277	0.961	0.000	0.595	≥0.999

*N_S = 364; N_U = 361

Copy of Student individuality survey (SIS)

Part I: Student Information

1. Gender Identity:
   - ○ Female
   - ○ Male
   - ○ Gender non-binary/Other
   - ○ Prefer not to say

2. Ethnicity:
   - ○ Hispanic or Latino
   - ○ Not Hispanic or Latino
   - ○ Prefer not to say

3. Race (You may select all that apply)
   - ☐ American Indian or Alaska Native
   - ☐ Asian (South/East)
   - ☐ Black or African American
   - ☐ Middle Eastern/North African
   - ☐ Native Hawaiian or Other Pacific Islander
   - ☐ White
   - ☐ Prefer not to answer

4. Are you in the first generation in your family to attend college?
   - ○ Yes
   - ○ No
   - ○ Prefer not to answer

5. How many years/semester of high school chemistry did you take?
   - ○ I have not taken high school chemistry
   - ○ I have taken 1 semester of high school chemistry
   - ○ I have taken 1 year (2 semesters) of high school chemistry
   - ○ 1 or more years of high school chemistry and 1 year of AP chemistry
   - ○ 2 or more years of chemistry, but not AP chemistry
   - ○ I took a chemistry course through the International Baccalaureate diploma program

6. How many semesters of college chemistry have you taken? (Does NOT include AP Chemistry in high school)
   - ○ I have not taken any college chemistry courses
   - ○ At most 1 semester of preparatory chemistry
   - ○ At most 1 semester of general chemistry
   - ○ Up to 2 semesters of chemistry
   - ○ More than 2 semesters of chemistry

7. Which best describes your goal for a grade in this class?
   - ○ I want to earn an A
   - ○ I want to earn at least a B
   - ○ I want to earn at least a C
   - ○ I just want to pass this class

8. What is your primary reason for taking this course? (Check the one that best applies)
   - ○ I am taking this course as a prerequisite for medical school or another health-related profession
   - ○ I am taking this course as a requirement for my major or minor
   - ○ I am taking this course as a prerequisite for another course needed for my major.
   - ○ I am taking this course as a science elective, general elective, or core requirement.
   - ○ I am taking this course because I am interested in chemistry.

Part II: Learning/Studying

9. How often do you anticipate needing to cram to study for General Chemistry? (Cramming, defined as mass studying in the last day or two before the exam, rather than spread out over the semester)
   - ○ Always
   - ○ Usually
   - ○ Sometimes
   - ○ Usually never
   - ○ Never

10. [**Logic:** If Q9, “Never” is <u>NOT</u> selected] Do you believe cramming works well for you?
    - ○ Absolutely
    - ○ Somewhat
    - ○ Not at all
    - ○ I don't cram

11. How often did you attend lecture?
    - ○ Always
    - ○ Almost always
    - ○ Half the time
    - ○ Almost never
    - ○ Never

12. How often do you prepare before lecture, by reading the textbook, reading notes, or other means?
    - ○ Always
    - ○ Almost always
    - ○ Half the time
    - ○ Almost never
    - ○ Never

13. How often do you write your own notes during the lecture itself? (Not including the professor's notes)
    - ○ Always
    - ○ Almost always
    - ○ Half the time
    - ○ Almost never
    - ○ Never

14. [**Logic:** If Q11 “Never” is NOT selected] How often do you think you stay focused in lecture?
   - ○ Always
   - ○ Almost always
   - ○ Half the time
   - ○ Almost never
   - ○ Never

15. If you read the textbook/lectures notes on your own, how often do you write your own notes alongside?
   - ○ Always
   - ○ Almost always
   - ○ Half the time
   - ○ Almost never
   - ○ Never
   - ○ N/A, I don’t read the textbook/lecture notes

16. How did you study for the General Chemistry exams? Check all that apply
   - ☐ Reading the textbook
   - ☐ Reading my instructor's notes
   - ☐ Reading other instructors’ notes
   - ☐ Writing my own notes
   - ☐ Watching videos online (YouTube, Khan Academy, etc.)
   - ☐ Doing practice problems from the textbook
   - ☐ Doing practice problems I found outside the textbook
   - ☐ Redoing old online homework
   - ☐ Other: ____

17. Of the methods listed, which do you believe will be the most helpful when studying for a quiz/exam. Drag and drop into the appropriate box

	Most Helpful	**Somewhat Helpful**	**Not Helpful**
Reading the textbook			
Reading my instructor's notes			
Reading other instructors’ notes			
Writing my own notes			
Watching videos online (YouTube, Khan Academy, etc.)			
Doing practice problems from the textbook			
Doing practice problems I found outside the textbook			
Redoing old online homework			

18. If you are working on a problem and you cannot solve it right away, what is likely your next step?
   - ○ Look up answer/solution and follow along
   - ○ Ignore it and move on
   - ○ Find a friend to help
   - ○ Find an instructor/TI to help
   - ○ Leave it and come back to it later
   - ○ Find a similar problem with a solution and try to follow along
   - ○ Read a section of the textbook (without looking at example problems)
   - ○ Other (specify) ____

19. **True or False:** I've found myself having to memorize much of the material instead of understanding it deeply.
   - ○ True
   - ○ False

20. Are you satisfied with your study habits?
   - ○ Yes
   - ○ Somewhat
   - ○ No

21. [**Logic:** If Q20 "Yes" is <u>NOT</u> selected] Do you know how to improve your study habits?
   - ○ Yes, I know what I need to do to improve
   - ○ No, I don't know how to improve

Chapter 6 | Creation of Academic Social Networks (ASNs) for Effective Online eLearning Communities

Abstract

College courses with a history of large enrollment sizes, such as General Chemistry, often rely on online homework systems to provide students with practice in applying new concepts to solve problems. Online homework systems offer many potential advantages, including instant feedback to students, adaptive learning capability, and valuable data to instructors that help identify learning obstacles on-the-fly. However, there does not currently exist network infrastructure that allows a global community of online learners to leverage this wealth of data, which may be generated from different online systems, in order to facilitate synchronous interactions, enable higher cognitive skills to be exercised, and enhance team learning in cyberspace. We have recently developed a framework for the creation of a new networking paradigm to build effective online learning communities: Academic Social Networks (ASNs). The framework integrates several key components: problem template engines (PTEs) that generate questions or exercises that test specific learning objectives, a critical skills network (CSN) that established an underlying fingerprint for each problem that is generated, and a virtual classroom environment (VCE) that allows synchronous interactions to take place in order to enable problem solving and team learning in cyberspace. These components act together to create an environment where students can work problems in order to assess mastery of specific learning objectives. Mastery is tracked at various levels of difficulty that are determined by the set of required critical skills needed to solve each problem. In this way, the CSN provides the foundation for which problems can be connected to one another, mastery of learning objectives can be tracked, and specific learning pathways can be analyzed. A student struggling with a problem that is testing a specific learning objective can reach out to the ASN to connect with other students that have demonstrated mastery of that learning objective at the same difficulty level or higher, and that have a track record at effective peer-mentoring, in

order to get help. Ultimately, this framework allows for the development of a tool that leverages the power of large enrollments to facilitate on-demand peer mentoring and delivery of custom instruction at scale. This work represents a significant advance in the development of novel online instructional technology that has promise to create new types of effective online learning communities that improve the quality of education. This may have a profound impact on how we connect with students enrolled in the growing massive open online courses (MOOCs) or those enrolled in large gateway courses at a university.

Introduction

Each semester at the Rutgers University - New Brunswick Campus, General Chemistry hosts over two-thousand students, many of whom are in their first year. Often described as a gateway course, it serves as a requirement for the majority of STEM majors and pre-professional health students.[153] General Chemistry is notoriously difficult, and traditionally sees a large percentage of students who are unsuccessful (e.g., either receiving a grade of D or F, or else withdrawing from the class), at least in their first attempt.[135, 183-185] This is particularly true of female and underrepresented minority students.[184-186] This is one of the contributing factors to the high attrition rates of STEM majors that are being experienced nationwide.[185, 187, 188] The situation has become considerably challenging to address in the face of increasing enrollments for which institutional resources such as classrooms, labs, and instructional staff are often unable to keep pace. Hence, there is great need to develop new types of infrastructure that offer cost-effective, scalable solutions, and new paradigms that allow the quality of education to improve as enrollment numbers increase.

In this chapter, we report the first results for the development and implementation of a framework for creation of academic social networks (ASNs) that offer a potentially powerful solution to the challenge of improving the success rate and quality of education in large enrollment gateway STEM courses. The implementation of this project took a phased approach. In the first phase, we launched an exploratory project to create an adaptive eLearning system for chemistry which allowed students to work towards a set of learning objectives, while being given some amount of guidance to help them achieve these goals. Learning objectives were assessed via customized problems delivered by Problem Template Engines (PTEs) that were driven by a network of chemical databases. Each problem that gets delivered by a PTE is characterized by a set of elemental critical skills required for its proper solution. The global array of critical skills is used to form an underlying Critical Skills Network (CSN) that allows problems with similar critical skill footprints to be connected to one another in a meaningful way. In the second phase, we implemented our first virtual classroom environments (VCEs) in order to tackle the pressing issues with our General Chemistry recitations. Recitations at Rutgers are meant to serve as small group learning sessions where concepts taught in class are applied to practical examples in an array of different contexts. However, due to issues regarding space and resources, student scheduling conflicts, transportation issues, and our ever-increasing enrollment numbers, there were hard limitations as to the number of students that could be accommodated in a given semester. In the fall semester of 2013, General Chemistry shifted to a completely online, virtual recitation environment. Students were able to choose their own schedule, attend multiple recitations per week, and receive individualized quizzes and prompt feedback.

While the VCEs and eLearning systems have great potential for students in and of themselves, a secondary benefit comes from the tremendous amount of data collected. This data can be as broad or as fine-grained as desired, and includes both academic data, such as content knowledge and mastery, as well as statistics surrounding participation patterns and engagement levels in the VCEs. All of this data may then be summarized to a more useable form, and build upon an individual student's profile. It is this profile that can help link a student to their peers, whether within their own classroom or not. These components culminate into our ultimate vision of the . This network serves to establish a community of students who wish to share and build their knowledge through helping others. In the end, we anticipate that both the learners and the helpers of the community will reap the benefits of such interactions.

General Chemistry eLearning System (GCeLS)

Addressing the Need

Homework is an opportunity for students to apply their knowledge gained from class and refine their problem-solving skills. Our General Chemistry students are typically given homework each week, to be done on their own time by a specified due date. This homework is given and completed via an online system, simply due to its convenience when working with such a large population. All students receive the same assignment, regardless of their professor, consisting of pre-made questions as selected by one of our instructors. Because all students take the same midterm and final exams, this seemed like the fairest way to account for any slight differences in the way that professors deliver the information to their classes. However, after thinking about our students and their individual needs, we wondered if this method was truly ideal. What if students could learn the same material, but in their own way?

Metacognition is often defined as “thinking about one’s own thinking” or the ability to reflect on one’s thought processes.[168] Students who practice successful metacognition are shown to perform better.[168, 189] Unfortunately, unless students have been explicitly taught in a way that fosters metacognitive processes, such as through continuous reflecting, they may lack these abilities.[135, 168, 190] A common complaint our instructors hear come from students who claim to be putting in the time, but not seeing positive results on the exams or quizzes. We suspected this was not due to a lack of hard work, but rather the lack of efficient work. Do our students know how to study? Are they able to recognize what they know, what they need help with, and how to obtain the missing pieces? The literature – as well as our intuitions – pointed towards no.[135, 191] Our students who are struggling may be unable to monitor their thoughts and methods in an effective way.

From our observations, we considered the two problems above to come up with a single solution. We wanted students to make their own paths towards learning, but because many may lack the metacognitive skills to do so, they needed some guidance. Ideally, we needed a system that was able to “understand” students and assess what they knew, while also providing a logical pathway for them to take. But before it could teach our students, we had to teach the system. Not only did it need to know when a student was wrong, but it needed to be able to pick out why the student was wrong. It would need to be able to bring students to a level where they could learn the missing concepts. Thus, everything needed to be arranged in a specific hierarchy. And of course, the system needed to be appealing. It had to be simple to set up, yet customizable for instructors, while also engaging and user-friendly for students. With these components in mind, we set out to create the General Chemistry eLearning system (GCeLS).

Approach and Development

In the first step, the system had to contain the information needed to give and solve problems. Starting from essentially nothing, this was a major undertaking. Information had to be stored in the databases in such a way that the different components could be connected. For example, an element table would hold information concerning each element, such as molar mass, density, thermodynamic data, etc. Then a compound table could be linked to the element table, allowing for an automatic calculation of the molar mass of each compound, based solely on the elements that it contains. A compound table could be linked to a reactions table, and so on. While figuring out the best way to enter data and connect the tables was a bit of a trial-and-error process, it was well-worth it in the long run. Once the databases could feed off of each other, generating chemical equations and other calculated data could be done automatically, even when raw data was changed or added. This allowed for simple, automated construction of a problem. Figure 6.1 illustrates this organization.

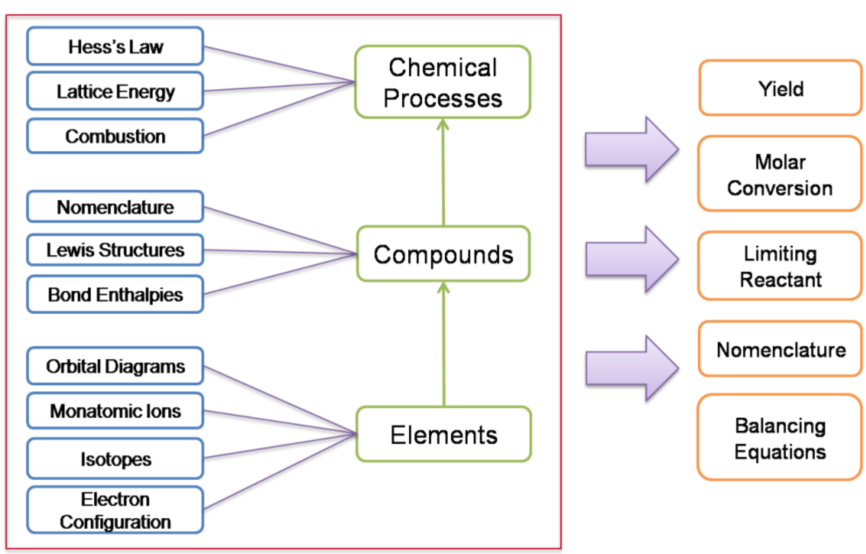


Figure 6.1. This overview of data organization shows how foundational aspects can ultimately feed into useable questions for students.

In the next step, we needed a hierarchy to arrange these problems. It was decided that instructors should be able to organize problems based on either the textbook that they are currently using, or by topic (regardless of the textbook). General Chemistry courses typically cover the same material, so the data would remain the same – only the organization would change. In the case of organization by textbook, the highest level would be the chapter. Chapters are typically arranged into several sections, so that became the next level. On the other hand, without a textbook, problems were instead arranged by topic first, and then by sub-topic, essentially mimicking the textbook model. After these two levels, the remainder of the hierarchy was identical.

Following the two uppermost levels, we begin to dig closer into the actual material. At the heart of the entire system live the learning objectives. These learning objectives are the simplest goal that a student can achieve, which can actually be measured. For example, a learning objective might be:

> Student can mathematically relate theoretical, actual, and percent yield to one another.

What we are trying to measure is whether or not, given two of the variables above, the student can solve for the third. Ultimately, our goal is to easily and accurately pinpoint conceptual holes, without mistaking them for underlying issues. This is the essence of the entire system: if the learning objectives are testing the most basic knowledge of an idea, then the system can determine whether or not a student knows what we want them to know. Of course, issues of validity will be addressed in the near future.

While we subscribed to the notion of using learning objectives, we also recognize that not all learning objectives are created equally. For example, consider the following two learning objectives:

> Student can define kinetic energy
> Student can mathematically relate an object's kinetic energy to its mass and velocity

While the first learning objective seeks a definition, considered rote knowledge, the second learning objective wants to know if a student can apply that knowledge to solve numerical problems involving kinetic energy. When it comes to assigning problems, we thought that it might be helpful to actually classify them according to these levels. While these issues came about naturally, Bloom's taxonomy seemed like a perfect match. We opted to use the revised taxonomy, which substitutes the noun-based nomenclature for verbs.[136] Granted, most of our learning objectives appeared to fall under the "Remember" or "Apply" categories, with some in the "Understand," it has opened up a door for us to try and create questions that explore areas requiring higher-cognitive abilities, and that are also suitable to our system. Not only did this classification help us, but we believe that making the students aware of these levels may prove beneficial to them as well.[192] While this is certainly an area worth pursuing, it has not been our main focus at the moment. Rather, it is something we will continue to work on in our next phase.

Once we established a set of learning objectives, the next hurdle was to translate them into a useable form. PTEs churn out the actual problems that students see. PTEs are not static, however. Within a given PTE, the problem can be manipulated. For example, the known and unknown variables can be swapped, such that a single PTE can produce two problems that ask for different variables. Alternatively, a given PTE could easily change the numbers and units associated with each variable. When giving a velocity, the system has the ability to turn out an infinite amount of numbers, in meters per second, miles per hour, feet per second, etc. Of course, this meant that each PTE had to be "told" what numbers or units are reasonable. In other cases, we had to define a relationship between the variables. For example, in searching for the velocity of an ejected electron, the value of the threshold frequency should always be less than the value given for photon frequency. Once these relationships and constraints were established, however, the system automatically followed these rules for all problems. While algorithmic problem manipulation has been seen before, it is still unclear whether or not it actually improves students' metacognitive skills and content knowledge.[190] Still, we thought it would be useful for students to see how the same question could be asked in multiple ways, as it could help alleviate the notorious issue of "plug-and-chug." Rather than pattern-searching, students would have to actually consider the variables at hand, and then determine the missing piece.

Aside from manipulating a problem, the difficulty of each problem could be adjusted such that students need to perform extra steps to achieve an answer. A yield problem at the most basic level could, for example, explicitly state the actual and theoretical yields of a reaction in moles. To find the percent yield, students only need the relationship between the three variables. We needed problems that were not only more interesting, but could test the student at a higher level for a given learning objective. How else could this problem be asked, while still testing the original learning objective?

This is where the idea of critical skills came into play. Rather than explicitly stating the theoretical yield, students could determine this variable by themselves from a balanced chemical equation and a starting amount of a reactant in moles. For this to happen, students must understand stoichiometric conversions. When the "Stoichiometry" critical skill is turned on, this is how the problem will be given. Alternatively, students may need to perform a grams-to-moles conversion, or balance the chemical equation themselves. All of these additional steps are called critical skills, and can be tuned to adjust a given PTE. Some PTEs have few possible critical skills, while others have many. As students progress in the course, critical skills may be added to test newer knowledge. While other online programs claim to allow for similar customization or randomization, our program's design is such as that it will lead directly to the seamless integration with the ASN, which will be discussed later in this chapter. Additionally, it is through the integration of critical skills into our PTEs that allow for instructors to be able to customize their assignments on a very fine-grained level.

Critical skills serve two main purposes, but we will only discuss the first at the moment. It has been shown that students commonly view chemistry as a disconnected series of facts, and often have difficulty applying identical skills across multiple topics.[15]

For example, students may learn stoichiometry in the chapter on thermodynamics, and later on in the chapter on electrochemistry, without realizing that the underlying skills apply in the same way. By involving the same critical skills throughout various topics, students may see how these skills are consistent and independent of context. It allows them to continually apply old knowledge to new situations, thus strengthening their old knowledge and forming more connections.

This organization achieves two of our goals: to allow instructors to have as much or as little customization as they desire, and to allow students to be guided down a custom path to achieve the various learning objectives. In the first, instructors may choose to have their homework correspond to a particular textbook, or they can simply select the topics. If they wish, they can go down the list even farther, selecting by subtopic, learning objective, or even PTE. They may choose to exclude certain material or critical skills.

On the flip side, the pathway a student takes to achieve a learning objective is completely dependent on what they already know. Constructivism and Meaningful Learning Theory rely heavily on students' prior knowledge.[7] It is thought that if we, as instructors, are able to get into the minds of our students and ascertain what they already know, we can begin to build new knowledge off of that. Realistically, this is not an attainable task for an instructor in such a large class. If a student begins with a PTE that has two critical skills turned on and they obtain an incorrect answer, our system will ideally be able to determine why. If the submitted answer indicates that the student did not balance the chemical equation, the student will return to a level in which they learn to balance chemical equations. Once the student proves that they understand that critical skill, they may return to a problem similar to the original one to solve again. If it is determined that the student is missing the very basics of a percent yield problem, they may be given a problem without any critical skills turned on to practice first. Typically, the system begins at an average level. If the student quickly masters a topic at that difficulty, then they will advance quicker. Those who struggle more will be given additional problems to solve and may need to take a few steps back before being able to move forward. In this way, students who are well-prepared will master a learning objective quicker, while students who require more help are able to receive it. Students do not waste time on problems they can already solve, and instead spend more time on problems that they need help with. Two students approach the same learning objective from unique paths suited for their individual needs. Other programs report to offer similar adaptive capabilities, and we felt that this aspect was essential. Our program takes this adaptability one step further by using the individual student's pathways to make important decisions for the student, particularly concerning their role in the ASN. The remainder of this chapter will begin address how these factors and the program's decisions culminate into important connections that link students based on these unique pathways. To the best of our knowledge, other online homework programs do not offer these capabilities.

Difficulty and Mastery

As mentioned, critical skills serve dual purposes. While the first was meant to help the student, the second allows us to assess a student's progress. Using these critical skills, we are able to test a given learning objective at different difficulty levels. Each question posed to a student is associated with a specific level of difficulty, and this level is a function of several components. For one, some topics or subtopics are inherently more difficult than others. Secondly, any given PTE can adjust its difficulty level by tuning the critical skills associated with it. As additional critical skills are added, the difficulty level of the problem increases. These factors go on to affect a student's "Mastery Level," a measure of how well a student knows a given learning objective, subtopic, or topic. Mastery is also dependent upon the expectations of the student. A student in an Honors-level General Chemistry course at a university is held to a higher standard than a high school student. Figure 6.2 illustrates this hierarchy.

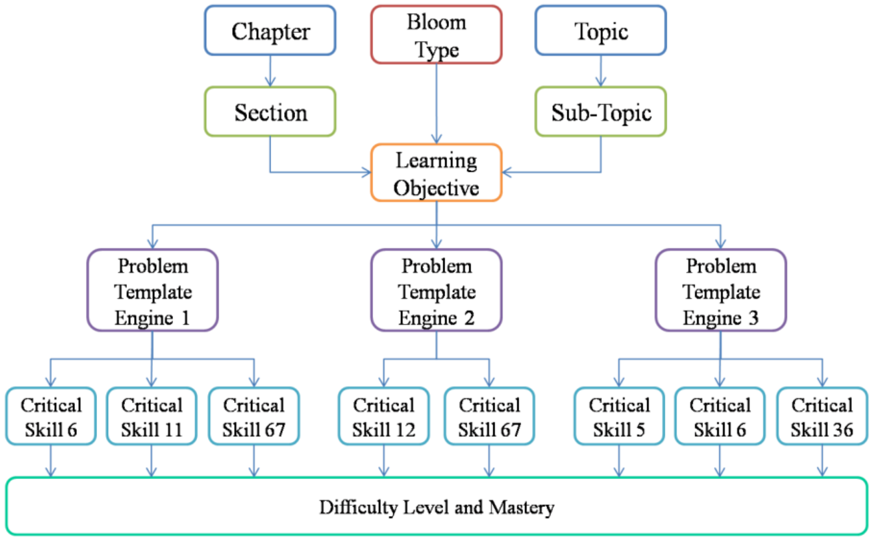


Figure 6.2. The hierarchy of desired content knowledge centers around a learning objective, tested by the problem template engines and tunable critical skills, which ultimately measure a student's mastery of the content.

We have established an algorithm that will take all of these factors into account and simply inform students (and their instructors) when they have mastered a given area. In order for a student to master the learning objective, they must prove that they can complete the problem regardless of the way it is asked and of which critical skills are turned on. In order to maintain a mastery status, however, students will be consistently re-tested on the concepts that they have already completed in order to ensure proper retention. Failure to successfully complete the old material will result in a student's loss of mastery status and the program will direct them to additional practice. If the student consistently and successfully retains the information, the system may re-test this material less often as time goes on.

Data Collection

In addition to providing the guidance students may require, such that they become more aware of their strengths and weaknesses, this online homework system produces an enormous amount of data. From general information like masteries to minute details like attempts on a single PTE, this data can be collected to help us understand more about the learning process and how to help those in need. Because the system is tracking the students, they receive immediate feedback about their progress. They are able to assess their standing in a more specific way, rather than as a simple percentage or letter grade. Our basis for these methods are Vygotsky's theory of zones of proximal development, and the related idea of scaffolding.[5] Successful scaffolding has been shown not only to help students obtain the content knowledge, but also to build on their cognition and metacognition skills and encourage self-regulated learning, particularly for lower-achieving students.[193-195] It is our hope that students not only use this information to solve homework problems, but also when making choices about independent studying.

Instructors can analyze the data broadly or at a fine grain, and may be able to provide appropriate intervention when needed. This includes an email system that is customized to fit each student. For example, a single message can be written to address multiple issues. If a professor wants to single out students who have been procrastinating, they can write a general message sent to all those who begin their homework past a certain date. If they wish to target students struggling with a particular concept and recommend additional practice problems or another resource, they can. All messages can be combined in a single email, with each part only showing up for those students that it applies to. Thus, students who procrastinate *and* are struggling with acid-base equilibria will receive one version of the email, while students who are only having issues with acid-base equilibria will not receive the first part. In the time it takes to write one email, instructors may send out emails to the entire class that are customized to fit each of their personal situations.

Virtual Classroom Environment

Addressing the Need

As technology improves and enrollments grow, we have seen more and more use of the virtual space in classrooms.[116, 196] Our university was of course no exception to the enrollment trend, and establishing a VCE seemed like a logical next step in order to provide students with additional academic support. Students are comfortable working in the virtual space, so it only made sense to meet them where they already are. We wanted to offer students the ability to form study groups, either on their own or under the facilitation of an instructor, which they could attend from the comfort of their own home and at a time convenient to them. All we needed was a platform suitable to communicating and working out chemistry problems. Equipped with a talented team of programmers and the support of the department, we made the push towards establishing our own system of VCEs.

Implementation

To start, it was of utmost importance that the system be user-friendly to both the students as well as the instructors. Most of the instructors, if not all of them, had previously only held physical, in-person class sessions. Learning to interact with students in a virtual setting after being conditioned to traditional teaching comes with a bit of a learning curve. To complicate this by using a clumsy, intricate system would surely be one way to lose the faculty's support. Instead, we focused on finding a system that would best mimic an actual classroom, with straight-forward tools and commands.

With a similar mindset for the students' side, we needed to ensure that there was first and foremost, no loss of learning. We considered all of the necessary operations of a smoothly-running classroom, and brainstormed ways in which we could implement these same components in a virtual setting. While we anticipated that the students would be relatively tech-savvy, we also knew that we could not make this assumption for all students. Not only did the system have to be straight-forward to use for the instructors, but the students had to learn how to use the system as well. Coupling this with the wide variety of possible laptop/computer settings, operating systems, and browsers, it was clear that the system needed to also be accommodating. In the end, the decision was made to create our own, in-house web-based application for the job. Students would need to have a steady internet connection and create their own account; however, they would not need to install any software or purchase extra equipment, aside from a few routine computer updates and a particular (free) internet browser. By creating our own system, it provided the flexibility needed to customize the settings to suit the needs of our classroom.

For a functional VCE, there were a few basics that we needed – namely a space to work out problems and a means of communication. We created a virtual white board that would allow the students or the instructor to write on just as they would on a normal chalk board or piece of paper, while others could watch in real-time. We offered a variety of pens and highlighters, as well as the ability to insert text and create or delete additional white boards. In a study group, students could have their own private whiteboard to work out problems, as well as a public board that everyone could see. Students can hear one another speaking through a microphone, and have the ability to see others via a webcam if they choose to. In this way, students can see and hear one another while simultaneously watching the white board, just as in real life. This lends a personal touch to the system that can easily be lost in a virtual space. If students wish to type to one another instead, we created a chatbox that allows them to do so.

Once we took care of the basics, our aim was to facilitate group work as much as possible. By creating an interface with GCeLS, students could import problems on any topic into their study group. Rather than having to search for a problem and type it out, this could be done quickly and easily. Likewise, because of the way the system is designed, each problem generated was unique. A group could now work together to solve novel problems.

Chemistry Interactive Problem-solving Sessions (ChIPS) – An Alternative to Recitations

Like most large universities, Rutgers General Chemistry is divided up between two semesters. Although most students take the first semester in the fall and second semester in the spring, a few hundred students do end up enrolling in the “off-sequence” courses each semester for a variety of reasons. This totals around 2,000 students taking General Chemistry at a time. In years past, General Chemistry students had to register for a specific lecture time, which was linked to a particular recitation slot. The large numbers, combined with the inflexibility of registration and limited space often led to overcrowded recitations, delayed registration, and the turning away of students from the course. Those turned away were forced to either take the class during the summer, a costly option for many, or fall behind in their program's curriculum. It was clear to the faculty that a change had to be made, but how to go about implementing any type of reform was not so evident. The solution had to be flexible, while still providing sufficient academic support for the course. At the same time, we had just begun to use the VCEs that we developed. Perhaps this was perfect timing!

In the fall semester of 2013, we launched our Chemistry Interactive Problem-solving Sessions (ChIPS) in lieu of our previous, traditional recitations. At the core, the operations of our VCE did not change much to accommodate these new recitations. Instructors still had a white board, equipped with the same writing tools. The main difference, however, is that the students could not write on the white board. Being that there was virtually no limit to the amount of students who could attend, giving them the ability to also write alongside the instructor would be, at best, distracting. Instead, the instructor runs the show. It is his or her face that is recorded while speaking, and the students watch and listen. Students could still type their questions or comments into a chatbox, or record their voice to be played at the instructor's discretion. Because the system had already been interfaced with eLearning, it was simple to give students quizzes at the end of each session. GCeLS could randomly generate a unique quiz for each student, based on the material discussed during class.

The boundaries for recitation do not stop with the basic VCE features, however. While students are seemingly watching the white board while the professor speaks, what they are actually seeing is the instructor's screen. If the instructor decides to step out of the recitation's web browser, the students will see this as well. Instructors took advantage of this by showing students videos of chemical reactions or molecular modeling simulations. Taking this a step further, we implemented the Glass Pane feature, which allows the instructors to actually annotate any web page, image, video, or document that they pull up on the screen, using a pen tool. Essentially, a virtual glass pane is placed over the screen and can be written on – a useful feature that cannot be found in a traditional classroom. Not only could instructors pull up other web pages, but they could write directly on top of the web page to edit or highlight something important with ease. To the best of our knowledge, this could not be done with other live-streaming applications. This eliminated the need for additional equipment, such as a projector or tablet, and could be done directly on an instructor's laptop.

As the first semester progressed, the technology team welcomed feedback and quickly implemented updates to improve the quality of the recitations. For example, instructors wanted to be able to use PowerPoint slides during their recitations. This is useful for showing diagrams and reference tables, pulling up lecture slides, or even just importing pre-made practice problems. Instructors can still approach their recitations in their own way, and many of them prefer to prepare material ahead of time to pull up. This feature allows them to do so, to the extent that they wish. Next, the team made some improvements to the chatbox. Useless words and phrases, such as greetings or unrelated chatter, are filtered out. This ensures that the important text, such as a question for the professor, is not pushed to the bottom of the queue. A polling feature was implemented to allow instructors to ask for a "quick show of hands," when asking questions. Students could select their option and the results are shown immediately on the screen. Feedback was not limited to instructor needs, however. As a request from students, the actual white boards from recitations were able to be saved and uploaded as images on the course website. This way, students no longer need to rush to copy notes. Instead, they could focus on watching and listening to the instructor, while referring to the notes at a later time. Each of these changes, along with some other minor developments, arose simply through feedback from users on both ends. Our technology team was not only receptive to these changes, but they were able to implement any requests very quickly.

Benefits of the Virtual Classroom Environment

Even after the first semester, both the students and the instructors began to see the benefits of the online structure of recitations. Students are able to pick any recitation they wish to go to on a weekly basis, often determined by their schedule. They are not attached to a designated recitation and thus the issues surrounding scheduling and make-up classes have virtually been eliminated. Students can attend multiple recitations each week, and they are allowed to retake quizzes for an improved score. This is a feature only made possible by the instant feedback that they receive. In the past, students would wait at least a week to receive their quiz scores back. In a fast-paced course like General Chemistry, one week can be much too late to seek help, as topics change quickly and build upon one another. We have found from our own experiences that some students will attend multiple recitations, even if their original quiz scores were satisfactory, leading us to believe they were intrinsically motivated to do so. Some students have a preference for certain instructors, and they, too, benefit from being able to choose their recitations each week. The students are able to attend these recitations from the comfort of their homes, dorms, or anywhere else with an internet connection. For the commuters, this can come in handy, particularly during inclement weather.

On the flip side, instructors also had positive comments for our team. The chatbox does not disclose a student's name, offering some anonymity. Instructors have often commented about the increase in participation, and we believe it is because students feel more comfortable speaking when others cannot see or identify them. It has been shown on occasion that there are gender gaps in traditional classroom participation, with female students participating less and being treated differently by instructors compared to their male counterparts.[196] Online learning may be a way to close such a gap. Instructors no longer have to create or grade quizzes each week, as they are automatically generated and graded, which allots them more time to devote to preparing their recitations. During this preparation, the options are endless and more easily facilitated compared to a regular classroom. Instructors can pull up lecture slides, write on a white board, go to a video demonstration, and open up practice problems in a matter of seconds. There is no pause between writing on a white board, setting up a projector, and going back and forth between the slides and board, as there is in a traditional classroom. Coupled with the higher levels of interaction, instructors have a better flow in their classroom and the learning process is more continuous.

The Big Picture – Tying it All Together

The Critical Skills Network

We have already defined critical skills and their main purposes in aiding student learning. They help connect previously-mastered concepts to newer ideas, such that students are able to get a feel for the "big picture." However, the critical skills themselves can be connected to one another, creating the Critical Skills Network (CSN). Figure 6.3 gives an example of one such network. Within the CSN, a single critical skill may be connected to only one other critical skill, as a result of a hierarchy, or it may combine with one or more other critical skills to produce additional ones. Such a network comes into play when determining a student's mastery and future goals. However, the CSN also plays a crucial role in helping us to understand how to connect our students to one another, creating a meaningful network of student-student interactions.

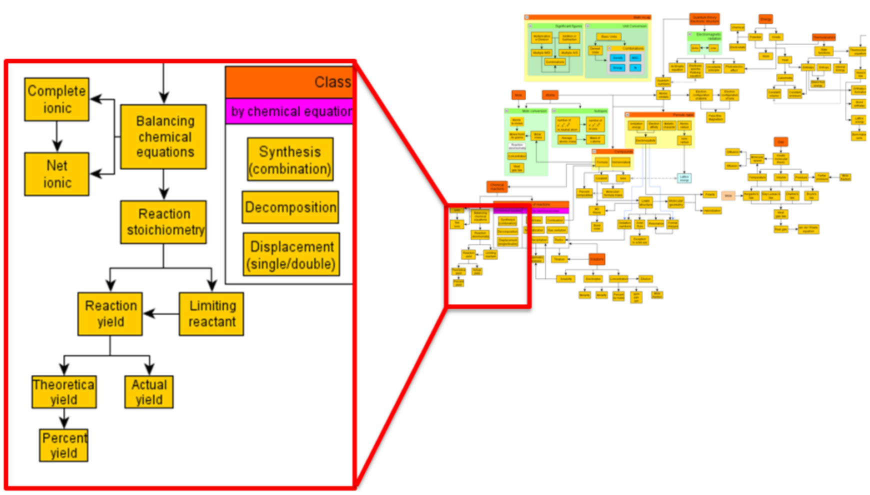


Figure 6.3. A small section of the critical skills network demonstrates how individual critical skills connect with one another or build further.

The Academic Social Network – The Incentive

In the Rutgers Chemistry Department, we run a teaching internship program for General and Organic Chemistry. This program is based off of the peer leadership model, in which former students facilitate learning with current students. While unique to Rutgers, it does share similarities with the Peer-Led Team Learning model, as well as other models founded on peer mentorship.[197] From our own experience with the teaching interns (TIs), we have seen the positive effects on both the students and the interns themselves. The interns have reported that they receive great enjoyment out of helping others, and the students ideally have someone more "on their level" to help explain the material. In addition to the TI program, we run a popular group on a social media website that allows students in the course to communicate with each other. They often ask questions and other members will reply with help. While the site sees a great deal of traffic each day, it became clear that perhaps it is not ideal for working with chemistry problems. Students are limited to "abc" text, they cannot write equations or draw molecules, and often times, the communication is asynchronous. Likewise, the group is limited to only students in this specific course. These obstacles prompted us to wonder if there was a way to combine the social aspects of the online site with technology and data in order to create what we termed an academic social network (ASN).

The social incentives for the network already exist for many of these students. They enjoy helping one another solve problems, and they spend some portion of their day on social media websites (some students spend more time than others!). Meeting them in their own world, where they are already comfortable, seems like a logical fit. Likewise, between the quizzes given during recitation and the online homework system, we had access to potentially an incredible amount of data. What if this data could be used to link students together? How well a student performs on a given topic or even a given learning objective becomes a part of their individual profile. The time of day that they work on their homework becomes a part of their individual profile. Their level of study, location in the world, etc., could all potentially become a part of an individual's profile. Implementing a peer rating system as to how helpful they have been in the past can also shape their profile. This way, whether a student is stuck on a titration problem at 10:00 AM on a Monday morning or an electrochemistry problem at 3:00 AM on a Wednesday morning, they can be linked to someone who can help them.

The next step would be to provide students with a platform that is more suitable to the context of academia and solving problems that require text, images, and mathematical equations. What better than using our own VCE as the foundation for the ASN? Students can form study groups on their own, or join other study groups in progress. All communication is synchronous, which may be appealing to those who are experiencing some frustration with a problem or concept that they cannot get past. This is in stark contrast to forums, in which students post a question and wait for someone (who may not be knowledgeable or helpful) to answer. Currently, most online discussion takes place in the form of asynchronous communication.[198-200] While this has been proven to provide various benefits when used as a course enhancement, including creating a sense of community, we believe the synchronous route will be more efficient and lessen the sense of "distance" in distance learning. Some studies have focused on the employment of synchronous learning, and while successes are evident, common issues are the need for additional equipment, the loss of personability, and inflexibility of use.[201, 202] These issues are alleviated with our system, as everything is run as an online web application, eliminating the need for software, students can see each other if they choose to, and students have the ability to type, speak, or draw on whiteboards in order to maximize flexibility in communication.

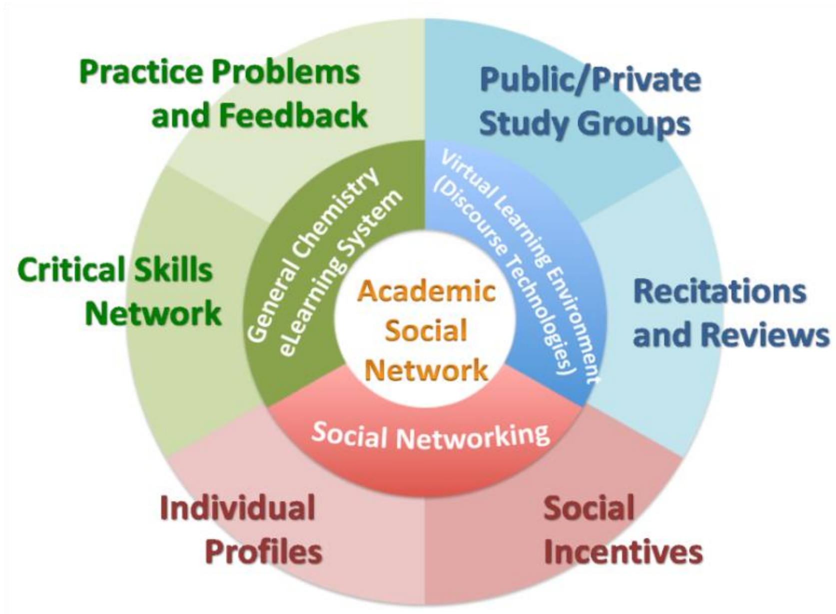


Figure 6.4. The various components of the Academic Social Network

Figure 6.4 summarizes the various components that feed into the ASN. The ASN is an invaluable tool for connecting students to one another. Our eLearning system provides the content knowledge and ability to measure a student's success and areas of improvement based on a network of critical skills. The virtual classroom environment currently in place allows students to communicate with one another, or an instructor, in an environment that they feel comfortable in, with tools necessary to facilitate learning chemistry. As far as social networking goes, students are already active in that field on their own, providing all the incentive needed. The ASN connects all three of these elements and has the potential to revolutionize the way we conduct online learning and collaboration in the classroom. But the possibilities stretch farther than that. Professors have the ability to give massive review sessions that can both be synchronous, with live students in attendance, as well as recorded for those who could not join to watch later. Massive Open Online Courses (MOOCs) have gained traction lately for offering free education to anyone in the world with an internet connection. Students enrolled in one of these courses can use the VCEs to attend learning sessions, and then turn to the ASN for additional classroom support from their peers.

Acknowledgments

The authors acknowledge support from the National Science Foundation (TUES grant 1245527), as well as generous support from the Rutgers School of Arts and Sciences Entrepreneurship Program. The authors are grateful for advice and input from Chris Scherer and John Brennan.

Appendix A| Institutional Review Board Acceptances and Documentation

IRB Acceptance Notification/Exemption, IRB Protocol #15-813

RUTGERS

Office of Research and Regulatory Affairs
Arts and Sciences IRB
Rutgers, The State University of New Jersey
335 George Street / Liberty Plaza / Suite 3200
New Brunswick, NJ 08901

orra.rutgers.edu/artsci
732-235-2866

August 29, 2018

P.I. Name: Arieh
Protocol #: E15-813

Emily Boginsky Arieh
Dept. of Chemistry and Chemical Biology
95 East 9th Street
Clifton NJ 07011

Dear Emily Arieh:

This project identified below has been approved for exemption under one of the six categories noted in 45 CFR 46, and as noted below:

Protocol Title: "Using Student Activity Patterns to Provide Effective and Immediate Intervention"

Amendment Exemption Date: 8/25/2018 **Exempt Category:** 1

This exemption is based on the following assumptions:

- **This Approval** - The research will be conducted according to the most recent version of the protocol that was submitted.
- **Reporting** –ORRA/Arts & Sciences IRB must be immediately informed of any injuries to subjects that occur (within 24 hours) and/or problems (e.g., subject complaints) that arise, in the course of your research within a timely manner (within 5 business days). Visit our website for more information on reportable events, https://orra.rutgers.edu/reportable-events; **Modifications** - Any proposed changes MUST be submitted to the IRB as an amendment for review and approval prior to implementation;
- **Consent Form (s)** - Each person who signs a consent document will be given a copy of that document. If you are using such documents in your research. The Principal Investigator must retain all signed documents for at least three years after the conclusion of the research;

Additional Notes:	• **Amendment Approval to Exemption granted on 8.25.18 for (1) addition of research personnel: Marc Muniz and Christine Altinis; (2) addition of two survey inventories for General Chemistry; (3) addition of a quick instrument (M-ASSIST) to measure students' study habits to the end of the previously approved CHEMX survey; (4) update to protocol to conduct 6 observation of students in the in-person Active Learning Recitations in the first semester of General Chemistry. The observations will include audio and visual data collection; (5) addition of same in person Active Learning Recitations observing the actions of the instructors using Classroom Observation Protocol for Undergraduate STEM (COPUS).** • ***NOTE: Reviewer has determined that this study is no longer Expedited, under categories 5,6,7 and can be deemed Exempt under Category 1.**

Failure to comply with these conditions will result in withdrawal of this approval.
Please note that the IRB has the authority to observe, or have a third party observe, the consent process or the research itself. The Federal-wide Assurance (FWA) number for the Rutgers University IRB is FWA00003913; this number may be requested on funding applications or by collaborators.

Sincerely yours,

Acting for -
Beverly Tepper, Ph.D.
Professor, Department of Food Science
IRB Chair, Arts and Sciences Institutional Review Board
Rutgers, The State University of New Jersey

cc: Darrin York

IRB Acceptance Notification, IRB Protocol #15-814

RUTGERS

Office of Research and Regulatory Affairs
Arts and Sciences IRB
Rutgers, The State University of New Jersey
335 George Street / Liberty Plaza / Suite 3200
New Brunswick, NJ 08901

orra.rutgers.edu/artsci

732-235-2866

May 29, 2020

Emily L. Atieh, Ed.M.
Department of Chemistry

P.I. Name: Atieh, Emily
Protocol #: 15-814Mx

Dear Ms. Atieh:

Initial **Amendment** ✓ **Continuation** **Continuation w/ Amend** **Adverse Event**

Protocol Title: "Evaluation of an Undergraduate Teaching Internship and Certificate Program

This is to advise you that the above-referenced study has been presented to the Institutional Review Board for the Protection of Human Subjects in Research, and the following action was taken subject to the conditions and explanations provided below:

Approval Date:	5/29/2020	**Expiration Date:**	5/28/2021
Expedited Category(s):	8c	**Final Enrollment:**	9,234

This approval is based on the assumption that the materials you submitted to the Office of Research and Sponsored Programs (ORSP) contain a complete and accurate description of the ways in which human subjects are involved in your research. The following conditions apply:

- **This Approval**-The research will be conducted according to the most recent version of the protocol that was submitted. **This approval is valid ONLY for the dates listed above;**
- **Reporting**-Reporting- Reporting—ORRA/Arts & Sciences IRB must be immediately informed of any injuries to subjects that occur (within 24 hours) and/or problems (e.g., subject complaints) that arise, in the course of your research within a timely manner (within 5 business days). Visit our website for more information on reportable events, https://orra.rutgers.edu/reportable-events.
- **Modifications**-Any proposed changes MUST be submitted to the IRB as an amendment for review and approval prior to implementation;
- **Consent Form**(s)-Each person who signs a consent document will be given a copy of that document, if you are using such documents in your research. The Principal Investigator must retain all signed documents for at least three years after the conclusion of the research;
- **Continuing Review**-You should receive a courtesy e-mail renewal notice for a Request for Continuing Review before the expiration of this project's approval. However, it is your responsibility to ensure that an application for continuing review has been submitted to the IRB for review and approval prior to the expiration date to extend the approval period;

Additional Notes:	▪ **Continuation Expedited Approval per 45 CFR 46.110;** ▪ **IRB Approval Has Been Provided For Data Analysis Only. PI Is To Contact The IRB Prior To The Recruitment Of Additional Subjects Or Further Interactions/Interventions With Subjects.**

Failure to comply with these conditions will result in withdrawal of this approval.
Please note that the IRB has the authority to observe, or have a third party observe, the consent process or the research itself. The Federal-wide Assurance (FWA) number for the Rutgers University IRB is FWA00003913; this number may be requested on funding applications or by collaborators.

Respectfully yours,

Acting For--
Beverly Tepper, Ph.D.
Professor, Department of Food Science
IRB Chair, Arts and Sciences Institutional Review Board
Rutgers, The State University of New Jersey

Cc: Darrin M. York

Letter of Advanced Notification of Research Study – General Chemistry Students, IRB #15-813

Dear Student,

You are invited to participate in a research study that is being conducted by Emily Atieh, Dr. Mary Emenike, and Dr. Darrin York in the *Department of Chemistry and Chemical Biology* at Rutgers University. The purpose of this research is to determine how students in the course experience general chemistry, learn content in online and in-person learning environments, interact with online course components, and prefer to receive extra help, through office hours, review sessions, study groups, or other means.

All students in the course will be invited to participate in the study, and all students who agree to participate will have their data included in the research study. Up to 2,000 subjects will participate in the study each semester, and each individual's participation will last approximately two semesters (about 30 weeks), or the entirety of a participant's time in General Chemistry I and II. Participants can choose to withdraw their consent at any time.

The study procedures include the following:

1. Participant completing a short survey to obtain basic demographics information and self-reported study habits (Approximately 2 minutes)
2. A second survey that asks about your views towards chemistry, to be given at the very beginning of General Chemistry and also at the end. There are no right or wrong answers to these statements. (Approximately 10 minutes)
3. A third survey regarding study habits
4. Research team obtaining physical/paper sign-in sheets from in-person recitations, office hours, workshops, review sessions, and study groups,
5. Research team obtaining electronic reports of attendance at and participation in online recitations, virtual office hours, and online review sessions

6. Research team obtaining General Chemistry assessment records, including homework, quiz, and exam records

Participation in this study is voluntary. You may choose not to participate, and you may withdraw at any time during the study procedures without any penalty to you. You may do so by contacting any member of the research team by phone, email, or in person. In addition, you may choose not to answer any questions with which you are not comfortable. If you have questions about your rights as a participant or any aspect of the study, you can contact Rutgers' Institutional Review Board for the protection of human subjects.

I have attached two consent forms: one for general consent to take part in the study, and one to consent to being audio-recorded. Please look these forms over carefully, and if you have any questions or concerns, please feel free to contact me by email, or we can arrange a personal meeting or phone call if you would prefer. I will attend all General Chemistry lectures during the first week of class and answer any additional questions you may have. Following your first homework assignment, you will be asked to make a decision whether or not to consent to the study.

Thank you for your time and I look forward to beginning this semester!

Sincerely,

Emily

Letter of Advanced Notification of Research Study – TIs, IRB #15-814

Dear Interns and Pedagogy Students,

I hope this email finds you well as you begin to prepare for this semester! As you may or may not already know, I am a graduate student in the Rutgers Department of Chemistry and Chemical Biology. This coming semester, I am conducting a research study on both the teaching internship, as well as the certificate program. While I have several goals for this long-term project, my main interests include examining how the internship and certificate program affect those who participate, and how it fits into the Chemistry Department.

The research project involves several components, including observations, interviews, audio recordings, surveys, and the gathering of personal information such as declared majors, GPAs, and individual course grades. Not every participant will be involved in all components.

There are four important things you should know about this study:

1. The study is confidential. This means that all of the data collected will be private, and no one outside of the research team will ever be able to link any data collected about you to your identity, even if the research is eventually published. This includes professors and instructors, aside from my Research Adviser Professor Darrin York.
2. Once the audio-recording has been fully transcribed, the audio file will be permanently deleted.
3. You may opt out of the study at any point in time, even if you have already chosen to consent, and all previously collected data will be permanently deleted.
4. Your decision to consent or not consent will have absolutely no bearing on any decisions that I make in the class, particularly regarding your grades and standing in the class.

I have attached two consent forms: one for general consent to take part in the study, and one to consent to being audio-recorded. They contain more details about the study, including what data will be collected and how it will be safeguarded. Note that you may consent to one form, and not the other.

Please look these forms over carefully, and if you have any questions or concerns, please feel free to contact me by email, or we can arrange a personal meeting or phone call if you would prefer.

I will discuss this study during our first meeting of the semester, and answer any additional questions you may have. At that point, you will be asked to make a decision whether or not to consent to the study. Thank you for your time and I am looking forward to starting this semester with you!

Sincerely,

Emily

Appendix B| Course Documents for the Teaching Internship and Certificate in Chemistry Education Program

Sample Questions for Interviewing New TI/CCE Applicants

Part I

3 minutes
The box below lists six qualities or assets. In your groups, rank them from most important quality to least. Also think of one essential quality that is not listed. Be prepared to discuss your conclusions with the audience.

Communication	Content Knowledge	Humility
Confidence	Conflict Management	Perseverance

Part II

10 minutes
Analogies are often used in teaching and education, as they connect what we already know to what we don't know. Come up with an analogy for any topic in General Chemistry that you could actually use to help someone understand that topic. You should consider the pros and cons of the analogy as well (How do the pieces connect? Where does the analogy fail? Etc.)

Part III

5 minutes
You are in a workshop with another TI, and while you are walking around, you hear them give a student some information that you don't believe is correct. The student wrote it down in their notes. What do you do?

Protocol for Interviewing New TI/CCE Applicants

Emily L. Atieh
Last Modified: April 15, 2018

Interview Protocol: For Teaching Interns/Graduate Students

Overview
Each interview will consist of 6-10 students. Students will be arranged in groups of 3-5, with no more than 2 groups total. There will be at least one permanent observer, a current TI or graduate student, who remains with that group for the entirety of the interview. The TI coordinator will rotate between groups.

Process
In the first four parts, students will work in a group (or independently, for Part IV) for the allotted time, and then be asked to present their work aloud.

Part I – Qualities of a TI (2 minutes)
Students will be given a list of qualities to rank in terms of importance.

Part II – Chemistry Activity (10 minutes)
Students will be given a chemistry-related prompt that asks them to create something.

Part III – Real-Life Scenarios (5 minutes)
Students will be given a potentially uncomfortable scenario in which they will have to decide what the right course of action is as a TI.

Part IV – Group Feedback (1 minute)
Students will turn to their right and give that interviewee positive feedback about their performance, and to the left and give that interviewee constructive criticism.

Question and Answer
Students may ask current TIs or the coordinator about the program, experiences, etc.

Instructions for Observers
1. Sit near your assigned group. You do not want to be so close that you interfere, but you need to be able to hear someone, especially if they are soft-spoken. Do not let the students see your notes.

2. Use the Transcript Sheet(s) that I will provide to take notes on what students are saying and doing. The more detailed, the better. Things to look for:

- Eye contact/body language – Do they look at others when they speak? Do they pay attention when the other group talks?
- Voice/Tone – Are they making their voice heard? Are they polite?
- Listening skills – Do they let others speak? Do they consider their ideas?
- Initiative – Do they offer to take notes? Do they read the prompt out loud?
- Creative – Do they offer ideas? Do they build upon others?
- Content – What are they saying? Is their chemistry correct?

3. Fill out the Interview Rubric for each student. Be thoughtful in your reviews and refer back to your transcripts. If you are unclear about anything, or think it does not apply, make a note. You will be asked for an overall recommendation at the end.

Sample Lesson from the Teaching Internship Program

Emily L. Atieh *Teaching Internship in General Chemistry*
Fall 2016

Week 8 – Alternate Conceptions

Last time, we worked on how to initiate questions to get a student thinking about a problem that they could not attempt. While this is important, typically students do come in with *some* ideas about chemistry. In fact, they likely have an entire *neuronal network* of ideas about how chemistry works in the world around us. Unfortunately, sometimes those ideas are incorrectly applied.

We call incorrectly applied concepts **alternate conceptions**, as opposed to misconceptions. The reason for this is that every thought, belief, idea, etc. is based on real-life experience. An experience cannot be wrong – but the interpretation or application of that experience can be incorrect.

Simply dismissing a student's idea as incorrect is not convincing enough. If the old idea is not addressed, that idea will continue to exist and propagate, and eventually the person will revert back to their old thinking. One goal of a good instructor is to figure out where the idea comes from and address it upfront so that the person sees how the ideas conflict with one another (called **cognitive dissonance**). At this point, the student needs to decide which idea to keep and which to toss. Helping them see *why* these alternate concepts exist and why it is not correct will help them make the decision and take responsibility in their own learning.

For this activity, please refer to the prompt that you were given. In your group, please address the following:

1. Where did the student go wrong?

2. What idea(s) does the student seem to either lack or apply incorrectly? Why do you think this is? In other words, where does this idea come from? Be specific.

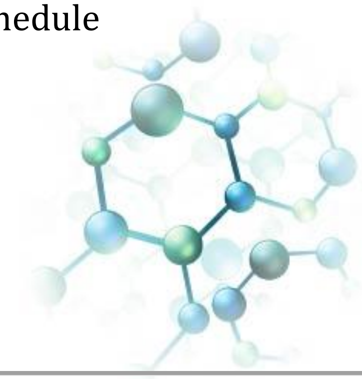
3. Write out your strategy for helping this student:
   a. How would you get the student to see their error?
   b. What questions might you ask them?
   c. How would you ensure you made a "permanent" change in their thinking?

Please write neatly and include your names, as I will be collecting this! ☺

Syllabus for Introduction to Chemistry Education

Introduction to Chemistry Education (CHEM 387)

Fall 2017 Course Schedule



Instructor: Emily L. Atieh
Office: [redacted]
Office Hours: Wednesdays 10am-12pm or by appt.
Phone: [redacted]
Email: [redacted]
Meeting Time/Location: F 1:40-3:00PM, SEC 217

COURSE SCHEDULE

The schedule below provides a list of topics for the entire semester. Note that changes may be made during the semester to accommodate for inclement weather or other unexpected occurrences. All readings and other assignments are due *before* coming to class. In other words, students should read the select papers by the date listed in the first column.

Date	Topics	Due
9/08	Introduction to Course	None
9/15	Classroom Discourse	Readings: 1. Knuth, R., Peressini, D., (2001). Unpacking the Nature of Discourse in Mathematics Classrooms. *Mathematics Teaching in the Middle School, 6*, 320-325.
9/22	Meaningful Learning & Constructivism Neural Networks	Readings: 1. Bretz, S.L., (2001). Novak's Theory of Education: Human Constructivism and Meaningful Learning. *Journal of Chemical Education, 78,* 1107-1116. 2. Zull, J. E. (2002) Chapter 5: What We Already Know, *The Art of Changing the Brain* (pp. 91-110). Sterling, VA: Stylus Publishing.
9/29	Alternate Conceptions	Readings: 1. Zull, J. E. (2002) Chapter 7: Only Connect!, *The Art of Changing the Brain* (pp. 111-126). Sterling, VA: Stylus Publishing. 2. Mulford, D.R., Robinson, W.R., (2002). An Inventory for Alternate Conceptions among First-Semester General Chemistry Students. *Journal of Chemical Education, 79*(6), 739-744.
10/06	Multiple Representations	Readings: 1. Johnstone, A.H., (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*, 75-83.

		2. Gabel, D. (2005). Chapter 7: Enhancing Students' Conceptual Understanding of Chemistry through Integrating the Macroscopic, Particle, and Symbolic Representations of Matter. In N. J. Pienta, M. M. Cooper, T.J. Cooper (Eds.), *Chemists' Guide to Effective Teaching* (pp. 77-87). Upper Saddle River, NJ: Pearson Prentice Hall.
10/13	Analogies in Teaching	Readings: 1. Glynn, S.M., Duit, R., Thiele, R.B., () Chapter 11: Teaching Science with Analogies: A Strategy for Constructing Knowledge. (247-260). 2. Zull, J. E. (2002) Chapter 7: Only Connect!, *The Art of Changing the Brain* (pp. 127-130). Sterling, VA: Stylus Publishing. 3. Orgill, M., Bodner, G. (2005). Chapter 8: The Role of Analogies in Chemistry Teaching. In N. J. Pienta, M. M. Cooper, T.J. Cooper (Eds.), *Chemists' Guide to Effective Teaching* (pp. 90-102). Upper Saddle River, NJ: Pearson Prentice Hall.
10/20	Metacognition & Reflection	Readings: 1. Rickey, D., Stacy, A.M., (2000). The Role of Metacognition in Learning Chemistry. *Journal of Chemical Education, 77*(7), 915-920. 2. Zull, J. E. (2002) Chapter 9: Waiting for Unity, *The Art of Changing the Brain* (pp. 153-175). Sterling, VA: Stylus Publishing.
10/27	Cooperative Learning and Group Discussions	Readings: 1. Johnson, D. W., Johnson, R. T., (1992). Implementing Cooperative Learning. *Contemporary Education, 63*(3), 173-180. 2. Mahalingam, M., Schaefer, F., Morlino, E., (2008). Promoting Student Learning through Group Problem Solving in General Chemistry Recitations. *Journal of Chemical Education, 85*(11), 1577-1581. 3. Towns, M. H., (1998). How Do I Get My Students to Work Together? Getting Cooperative Learning Started. *Journal of Chemical Education, 75,* 67-69.
11/03	Case Study – Classroom Dynamics and Reform	Readings: Group 1: Mooring, S.R., Mitchell, C.E., Burrows, N.L. (2016). Evaluation of a Flipped, Large-Enrollment Organic Chemistry Course on Student Attitude and Achievement. *Journal of Chemical Education, 93,* 1972-1983. Group 2: Hein, S.M., (2012). Positive Impacts Using POGIL in Organic Chemistry. *Journal of Chemical Education, 89,* 860-864. Group 3: Hockings, S.C., DeAngelis, K.J., Frey, R.F. (2008). Peer-Led Team Learning in General Chemistry:

		Implementation and Evaluation. *Journal of Chemical Education, 85*(7), 990-996. Group 4: Kelly, O., Finlayson, O. (2009). A Hurdle Too High? Students Experience of a PBL Laboratory Module. *Chemistry Education Research and Practice, 10,* 42-52.
11/09	Case Study – Learning Cycles	Readings: 1. Zull, J. E. (2002) Chapter 2: Where We Ought to Be, *The Art of Changing the Brain* (pp. 13-28). Sterling, VA: Stylus Publishing. 2. Etkina, E., Van Heuvelen, A., (2001). "Investigative Science Learning Environment: Using the process of science and cognitive strategies to learn physics." *Proceedings of the 2001 Physics Education Research Conference,* 17-20.
11/17	Case Study – Epistemology	Readings: 1. Mazzarone, K.M., Grove, N.P., (2013). Understanding Epistemological Development in First- and Second-Year Chemistry Students. *Journal of Chemical Education, 90,* 968-975.
11/22* (Wed)	Teaching Philosophies	None
12/01	Case Study – Metacognition in Practice	Readings: 1. Cook, E., Kennedy, E., McGuire, S.Y. (2013). Effect of Teaching Metacognitive Learning Strategies on Performance in General Chemistry Courses. *Journal of Chemical Education, 90,* 961-967.
12/08	**Class Presentations!**	

***Change in designation days, Wednesday 11/22 – go to Friday classes!**

Assignment and Due Dates

Below is a table of all assignments and due dates. For each (except the midterm) there will be a document in the Resources with instructions. For the midterm, the instructions will be given on the actual midterm itself.

All Class Due Dates:

Assignment	Notes	Due Date
Goals	• Submit via Assignments on Sakai • See rubric and instructions for details	Sun 09/15; 11:59pm
Paper I	• Submit via Assignments on Sakai • See rubric and instructions for details	Sun 10/22; 11:59pm
Midterm	• Submit via Tests/Quizzes on Sakai • Please read the instructions VERY carefully	Open: Sun 10/30; 8:00 pm Close: Sun 11/06; 11:59pm

Paper II	• Submit via Assignments on Sakai • See rubric and instructions for details	Wed 11/22 11:59 pm
Discussion Leadership Project	• Submit via Assignments on Sakai • See rubric and instructions for details	Submit: Thurs 12/07; 11:59pm Present: Fri 12/08 in class

Honors Due Dates:

Assignment	**Notes**	**Due Date**
Honors Topics	• See list of possible topics • Submit top 3 choices in class • Only for students taking Honors credit OR Extra credit	Fri 10/21; in class
Honors Presentation	• To be presented at our last meeting • See Honors folder for instructions	TBD
Honors Lit Review	• To be handed in at the time of your presentation • See Honors folder for instructions	TBD

References

1. Atieh, E. L.; York, D. M., Through the Looking CLASS: When Peer Leader Learning Attitudes Are Not What They Seem. *J. Chem. Educ.* **2020,** *97* (8), 2078-2090.
2. Atieh, E. L.; Chun, K. L.; Shah, R.; Guerra, F.; York, D. M., Creation of Academic Social Networks (ASNs) for Effective Online eLearning Communities. In *Online Course Development and the Effect on the On-Campus Classroom*, American Chemical Society: 2016; Vol. 1217, pp 109-126.
3. Atieh, E. L.; York, D. M. The Certificate in Chemistry Education. https://www.elearning.rutgers.edu/chem-cce (accessed 11/11/19).
4. Atieh, E. L.; York, D. M. The Teaching Internship in General Chemistry. https://www.elearning.rutgers.edu/chem-ti-program (accessed 11/11/19).
5. Vygotsky, L. S., *Mind in society: The development of higher psychological processes*. Harvard university press: Cambridge, MA, 1978.
6. Roscoe, R. D.; Chi, M. T. H., Understanding Tutor Learning: Knowledge-Building and Knowledge-Telling in Peer Tutors' Explanations and Questions. *Review of Educational Research* **2007,** *77* (4), 534-574.
7. Bretz, S. L., Novak's Theory of Education: Human Constructivism and Meaningful Learning. *J. Chem. Educ.* **2001,** *78* (8), 1107.
8. National Science Board. 2018. *Science and Engineering Indicators 2018.* NSB-2018-1. Alexandria, VA: National Science Foundation. Retrieved from https://www.nsf.gov/statistics/indicators/ (accessed 08/19/19).
9. *Two Decades of Change in Federal and State Higher Education Funding*; The Pew Research Center: October 2019.
10. Smith, A. C.; Stewart, R.; Shields, P.; Hayes-Klosteridis, J.; Robinson, P.; Yuan, R., Introductory Biology Courses: A Framework To Support Active Learning in Large Enrollment Introductory Science Courses. *CBE-Life Sci. Educ.* **2005,** *4* (2), 143-156.
11. Arendale, D. R., History of supplemental instruction (SI): Mainstreaming of developmental education. In *Histories of Developmental Education*, Lundell, D. B.; Higbee, J. L., Eds. Center for Research on Developmental Education and Urban Literacy, General College, University of Minnesota: Minneapolis, MN, 2002; pp 15-27.
12. Herrman, J. W.; Waterhouse, J. K., Benefits of using undergraduate teaching assistants throughout a baccalaureate nursing curriculum. *J. Nurs. Educ.* **2010,** *49* (2), 72-77.
13. Ganser, S. R.; Kennedy, T. L., Where it all began: Peer education and leadership in student services. *New Dir. Higher Educ.* **2012,** *2012* (157), 17-29.
14. Shook, J. L.; Keup, J. R., The benefits of peer leader programs: An overview from the literature. *New Dir. Higher Educ.* **2012,** *2012* (157), 5-16.
15. President's Council of Advisors on Science and Technology (2012). *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics.* Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf (accessed 10/01/19).
16. Wilson, S. B.; Varma-Nelson, P., Small Groups, Significant Impact: A Review of Peer-Led Team Learning Research with Implications for STEM Education Researchers and Faculty. *J. Chem. Educ.* **2016,** *93* (10), 1686-1702.
17. Adams, W. K.; Perkins, K. K.; Dubson, M.; Finkelstein, N. D.; Wieman, C. E., The Design and Validation of the Colorado Learning Attitudes about Science Survey. *AIP Conf. Proc.* **2005,** *790* (1), 45-48.
18. Wallace, R. A., An alternative to assembly-line education: undergraduate teaching assistants. *Teach. Sociol.* **1974**, 3-14.

19. Lewis, S. E., Retention and reform: An evaluation of peer-led team learning. *J. Chem. Educ.* **2011,** *88* (6), 703-707.
20. Amaral, K. E.; Vala, M., What teaching teaches: Mentoring and the performance gains of mentors. *J. Chem. Educ.* **2009,** *86* (5), 630.
21. Preszler, R. W., Replacing lecture with peer-led workshops improves student learning. *CBE-Life Sci. Educ.* **2009,** *8* (3), 182-192.
22. Frey, R. F.; Fink, A.; Cahill, M. J.; McDaniel, M. A.; Solomon, E. D., Peer-Led Team Learning in General Chemistry I: Interactions with Identity, Academic Preparation, and a Course-Based Intervention. *J. Chem. Educ.* **2018,** *95* (12), 2103-2113.
23. Kopp, S. E., Undergraduate peer assistants in a large lecture course. *Phys. Educ.* **2000,** *35* (6), 423-427.
24. Gosser, D. K.; Roth, V., The workshop chemistry project: Peer-led team-learning. *J. Chem. Educ.* **1998,** *75* (2), 185.
25. Crouch, C. H.; Mazur, E., Peer instruction: Ten years of experience and results. *Am. J. Phys.* **2001,** *69* (9), 970-977.
26. Murphey, T., Near peer role models. *Teachers Talking To Teachers: JALT Teacher Education SIG Newsletter* **1996,** *4* (3), 21-22.
27. Murphey, T.; Arao, H., Reported belief changes through near peer role modeling. *TESL-EJ* **2001,** *5* (3), 1-15.
28. Singh, S., Near-peer role modeling: The fledgling scholars education paradigm. *Anat. Sci. Educ.* **2010,** *3* (1), 50-51.
29. Allen, D. E.; White Iii, H. B., A few steps ahead on the same path. *J. Coll. Sci. Teach.* **1999,** *28* (5), 299.
30. Streitwieser, B.; Light, G., When Undergraduates Teach Undergraduates: Conceptions of and Approaches to Teaching in a Peer Led Team Learning Intervention in the STEM Disciplines--Results of a Two Year Study. *Int. J. Teach. Learn. High. Educ.* **2010,** *22* (3), 346-356.
31. Allen, D. E.; White, H. B., Peer facilitators of in-class groups: adapting problem-based learning to the undergraduate setting. *Student Assisted Teaching: A Guide to Faculty-Student Teamwork, ed. JE Miller, JE Groccia and MS Miller. Bolton, MA: Anker Publications* **2001**.
32. Blackwell, S.; Katzen, S.; Patel, N.; Sun, Y.; Emenike, M., Developing the Preparation in STEM Leadership Programs for Undergraduate Academic Peer Leaders. *Learn. Assist. Rev.* **2017,** *22* (1), 49-84.
33. Gafney, L.; Varma-Nelson, P., Evaluating peer-led team learning: A study of long-term effects on former workshop peer leaders. *J. Chem. Educ.* **2007,** *84* (3), 535.
34. Tenney, A.; Houck, B., Learning about leadership: Team learning's effect on peer leaders. *J. Coll. Sci. Teach.* **2004,** *33* (6), 25-29.
35. Romm, I.; Gordon-Messer, S.; Kosinski-Collins, M., Educating Young Educators: A Pedagogical Internship for Undergraduate Teaching Assistants. *CBE-Life Sci. Educ.* **2010,** *9* (2), 80-86.
36. Hufford, T., The Role of the Undergraduate Student in Teaching and Learning Biology. *Atlas J. Sci. Educ.* **2017,** *1*, 38-42.
37. Gordon, J.; Henry, P.; Dempster, M., Undergraduate Teaching Assistants: A Learner-Centered Model for Enhancing Student Engagement in the First-Year Experience. *Int. J. Teach. Learn. High. Educ.* **2013,** *25* (1), 103-109.
38. Mendenhall, M.; Burr, W. R., Enlarging the Role of the Undergraduate Teaching Assistant. *Teach. Psychol.* **1983,** *10* (3), 184-185.
39. Schalk, K. A.; McGinnis, J. R.; Harring, J. R.; Hendrickson, A.; Smith, A. C., The undergraduate teaching assistant experience offers opportunities similar to the undergraduate research experience. *J. Microbiol. Biol. Educ.* **2009,** *10* (1), 32-42.

40. Otero, V.; Pollock, S.; McCray, R.; Finkelstein, N., Who is responsible for preparing science teachers? *Science* **2006,** *313* (5786), 445-446.
41. Martin, D. C., The Learning Center: A Comprehensive Model for Colleges and Universities. **1977**.
42. Arendale, D. R., Understanding the supplemental instruction model. *New Dir. Teach. Learn.* **1994,** *1994* (60), 11-21.
43. Finkelstein, N.; Turpen, C.; Pollock, S.; Dubson, M.; Iona, S.; Keller, C.; Otero, V., Evaluating a model of research-based practices for teacher preparation in a physics department: Colorado PhysTEC. *2005 Physics Education Research Conference* **2006,** *818*, 3-+.
44. Pollock, S. J., No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms. *AIP Conf. Proc.* **2005,** *790* (1), 137-140.
45. Hug, S.; Thiry, H.; Tedford, P. In *Learning to love computer science: Peer leaders gain teaching skill, communicative ability and content knowledge in the CS classroom*, 2011; ACM: pp 201-206.
46. Blat, C.; Myers, S.; Nunnally, K.; Tolley, P. In *Successfully applying the supplemental instruction model to sophomore-level engineering courses*, Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition, 2001; pp 1-6.911.
47. Loui, M. C.; Robbins, B. A. In *Work-in-progress-assessment of peer-led team learning in an engineering course for freshmen*, Frontiers in Education Conference, 2008. FIE 2008. 38th Annual, IEEE: 2008; pp F1F-7-F1F-8.
48. Mahalingam, M.; Schaefer, F.; Morlino, E., Promoting student learning through group problem solving in general chemistry recitations. *J. Chem. Educ* **2008,** *85* (11), 1577.
49. Hockings, S. C.; DeAngelis, K. J.; Frey, R. F., Peer-led team learning in general chemistry: Implementation and evaluation. *J. Chem. Educ.* **2008,** *85* (7), 990.
50. Vázquez, A. V.; McLoughlin, K.; Sabbagh, M.; Runkle, A. C.; Simon, J.; Coppola, B. P.; Pazicni, S., Writing-To-Teach: A New Pedagogical Approach To Elicit Explanative Writing from Undergraduate Chemistry Students. *J. Chem. Educ.* **2012,** *89* (8), 1025-1031.
51. Báez-Galib, R.; Colón-Cruz, H.; Resto, W.; Rubin, M. R., Chem-2-Chem: A one-to-one supportive learning environment for chemistry. *J. Chem. Educ.* **2005,** *82* (12), 1859.
52. Fingerson, L.; Culley, A. B., Collaborators in teaching and learning: Undergraduate teaching assistants in the classroom. *Teach. Sociol.* **2001**, 299-315.
53. Gallan, A. J.; Offner, G. D.; Symes, K., Vertical integration of biochemistry and clinical medicine using a near-peer learning model. *Biochem. Mol. Biol. Educ.* **2016,** *44* (6), 507-516.
54. Evans, D. J.; Cuffe, T., Near-peer teaching in anatomy: An approach for deeper learning. *Anat. Sci. Educ.* **2009,** *2* (5), 227-233.
55. Wade, P., Student tutors: An analysis of the creation of a peer-led tutoring inititative utilising the implementation staircase model. *J. Teach. Engl. Specif. Acad. Purp.* **2016,** *4* (2), 367-372.
56. Martin, D. C.; Blanc, R.; Arendale, D. R., Supplemental Instruction: Supporting the classroom experience. National Resource Center for the First Year Experience and Students in ...: 1996.
57. Golde, M. F.; McCreary, C. L.; Koeske, R., Peer Instruction in the General Chemistry Laboratory: Assessment of Student Learning. *J. Chem. Educ.* **2006,** *83* (5), 804.
58. Stewart, B. N.; Amar, F. G.; Bruce, M. R. M., Challenges and rewards of offering peer led team learning (PLTL) in a large general chemistry course. *Aust. J. Educ. Chem.* **2007,** *67*, 31-36.

59. House, J., Student Expectancies and Academic Self-Concept as Predictors of Science Achievement. *J. Psychol.* **1996,** *130* (6), 679.
60. House, J. D., Noncognitive Predictors of Achievement in Introductory College Chemistry. *Res. High. Educ.* **1995,** *36* (4), 473-490.
61. Tinto, V., *Leaving college: Rethinking the causes and cures of student attrition*. ERIC: 1987.
62. Seymour, E., The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account. *Sci. Educ.* **1995,** *79* (4), 437-473.
63. Tracey, T. J.; Sedlacek, W. E., The relationship of noncognitive variables to academic success: A longitudinal comparison by race. *J. Coll. St. Personnel* **1985,** *26* (5), 405-410.
64. Sutherland, L., Developing problem solving expertise: the impact of instruction in a question analysis strategy. *Learning and Instruction* **2002,** *12* (2), 155-187.
65. Kohl, P. B.; Finkelstein, N. D., Patterns of multiple representation use by experts and novices during physics problem solving. *Phys. Rev. Sp. Topics - Phys. Educ. Res.* **2008,** *4* (1), 010111.
66. Mason, A.; Singh, C., Do advanced physics students learn from their mistakes without explicit intervention? *Am. J. Phys.* **2010,** *78* (7), 760-767.
67. National Research Council. 2012. *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, D. T. N. A. P. h. d. o.
68. Chi, M. T. H.; Feltovich, P. J.; Glaser, R., Categorization and representation of physics problems by experts and novices. *Cognitive science* **1981,** *5* (2), 121-152.
69. Hardiman, P. T.; Dufresne, R.; Mestre, J. P., The relation between problem categorization and problem solving among experts and novices. *Mem. Cognition* **1989,** *17* (5), 627-638.
70. Charness, N.; Reingold, E. M.; Pomplun, M.; Stampe, D. M. J. M.; cognition, The perceptual aspect of skilled performance in chess: Evidence from eye movements. **2001,** *29* (8), 1146-1152.
71. Jarodzka, H.; Scheiter, K.; Gerjets, P.; van Gog, T., In the eyes of the beholder: How experts and novices interpret dynamic stimuli. *Learning and Instruction* **2010,** *20* (2), 146-154.
72. Beilock, S. L.; Carr, T. H.; MacMahon, C.; Starkes, J. L., When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied* **2002,** *8* (1), 6.
73. de Jong, T.; Ferguson-Hessler, M. G., Cognitive structures of good and poor novice problem solvers in physics. *Journal of Educational Psychology* **1986,** *78* (4), 279.
74. Redish, E. F.; Saul, J. M.; Steinberg, R. N., Student expectations in introductory physics. *Am. J. Phys.* **1998,** *66* (3), 212-224.
75. Otero, V. K.; Gray, K. E., Attitudinal gains across multiple universities using the Physics and Everyday Thinking curriculum. *Physical Review Special Topics - Physics Education Research* **2008,** *4* (2), 020104.
76. Enneking, K. M.; Breitenstein, G. R.; Coleman, A. F.; Reeves, J. H.; Wang, Y.; Grove, N. P., The Evaluation of a Hybrid, General Chemistry Laboratory Curriculum: Impact on Students' Cognitive, Affective, and Psychomotor Learning. *J. Chem. Educ.* **2019,** *96* (6), 1058-1067.
77. Mazzarone, K. M.; Grove, N. P., Understanding Epistemological Development in First- and Second-Year Chemistry Students. *J. Chem. Educ.* **2013,** *90* (8), 968-975.

78. Roscoe, R. D.; Chi, M. T. H., Tutor learning: The role of explaining and responding to questions. *Instr. Sci.* **2008,** *36* (4), 321-350.
79. Nestojko, J. F.; Bui, D. C.; Kornell, N.; Bjork, E. L., Expecting to teach enhances learning and organization of knowledge in free recall of text passages. *Memory & Cognition* **2014,** *42* (7), 1038-1048.
80. King, A., Structuring Peer Interaction to Promote High-Level Cognitive Processing. *Theor. Pract.* **2002,** *41* (1), 33-39.
81. Benware, C. A.; Deci, E. L., Quality of Learning With an Active Versus Passive Motivational Set. *Am. Educ. Res. J.* **1984,** *21* (4), 755-765.
82. Bransford, J. D.; Brown, A. L.; Cocking, R. R., *How people learn.* Washington, DC: National academy press: 2000; Vol. 11.
83. Shin, N.; Jonassen, D. H.; McGee, S., Predictors of well-structured and ill-structured problem solving in an astronomy simulation. *J. Res. Sci. Teach.* **2003,** *40* (1), 6-33.
84. Chen, C.-H.; Bradshaw, A. C., The effect of web-based question prompts on scaffolding knowledge integration and ill-structured problem solving. *J. Res. Technol. Educ.* **2007,** *39* (4), 359-375.
85. Ge, X.; Land, S. M., Scaffolding students' problem-solving processes in an ill-structured task using question prompts and peer interactions. *ETR&D-Educ. Tech. Res.* **2003,** *51* (1), 21-38.
86. Jonassen, D. H., Instructional design models for well-structured and III-structured problem-solving learning outcomes. *ETR&D-Educ. Tech. Res.* **1997,** *45* (1), 65-94.
87. Perkins, K. K.; Adams, W. K.; Pollock, S. J.; Finkelstein, N. D.; Wieman, C. E., Correlating Student Beliefs With Student Learning Using The Colorado Learning Attitudes about Science Survey. *AIP Conf. Proc.* **2005,** *790* (1), 61-64.
88. Xu, X.; Lewis, J. E., Refinement of a chemistry attitude measure for college students. *J. Chem. Educ.* **2011,** *88* (5), 561-568.
89. Lave, J.; Wenger, E., *Situated learning: Legitimate peripheral participation.* Cambridge university press: 1991.
90. Orgill, M., Situated cognition. *Theoretical frameworks for research in chemistry/science education* **2007**, 187-203.
91. Rutgers University Facts and Figures. https://newbrunswick.rutgers.edu/about/facts-figures (accessed 09/20/19).
92. Adams, W. K.; Wieman, C. E.; Perkins, K. K.; Barbera, J., Modifying and Validating the Colorado Learning Attitudes about Science Survey for Use in Chemistry. *J. Chem. Educ.* **2008,** *85* (10), 1435.
93. Adams, W. K.; Perkins, K. K.; Podolefsky, N. S.; Dubson, M.; Finkelstein, N. D.; Wieman, C. E., New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics - Physics Education Research* **2006,** *2* (1), 010101.
94. Bauer, C. F., Beyond" student attitudes": Chemistry self-concept inventory for assessment of the affective component of student learning. *J. Chem. Educ* **2005,** *82* (12), 1864.
95. Bauer, C. F., Attitude toward chemistry: a semantic differential instrument for assessing curriculum impacts. *J. Chem. Educ.* **2008,** *85* (10), 1440.
96. Galloway, K. R.; Bretz, S. L., Using cluster analysis to characterize meaningful learning in a first-year university chemistry laboratory course. *Chem. Educ. Res. Pract.* **2015,** *16* (4), 879-892.
97. Grove, N.; Bretz, S. L., CHEMX: An Instrument To Assess Students' Cognitive Expectations for Learning Chemistry. *J. Chem. Educ.* **2007,** *84* (9), 1524.
98. Elby, A.; Frederiksen, J.; Schwarz, C.; White, B. Epistemological beliefs assessment for physical science (EBAPS).

http://www2.physics.umd.edu/~elby/EBAPS/home.htm (accessed 09/20/19).
99. Pintrich, P. R.; Smith, D. A. F.; Garcia, T.; McKeachie, W. J., Reliability and Predictive Validity of the Motivated Strategies for Learning Questionnaire (Mslq). *Educ. Psychol. Meas.* **1993,** *53* (3), 801-813.
100. Munby, H., An Investigation into the Measurement of Attitudes in Science Education. **1983**.
101. Koballa Jr, T. R., Attitude and related concepts in science education. *Sci. Educ.* **1988,** *72* (2), 115-126.
102. Lewis, S. E.; Shaw, J. L.; Heitz, J. O.; Webster, G. H., Attitude counts: Self-concept and success in general chemistry. *J. Chem. Educ.* **2009,** *86* (6), 744.
103. Heredia, K.; Lewis, J. E., A Psychometric Evaluation of the Colorado Learning Attitudes about Science Survey for Use in Chemistry. *J. Chem. Educ.* **2012,** *89* (4), 436-441.
104. Kerby, D. S., The Simple Difference Formula: An Approach to Teaching Nonparametric Correlation. *Comprehensive Psychology* **2014,** *3*, 11.IT.3.1.
105. Elby, A., Helping physics students learn how to learn. *Am. J. Phys.* **2001,** *69* (S1), S54-S64.
106. Tien, L. T.; Roth, V.; Kampmeier, J., Implementation of a peer-led team learning instructional approach in an undergraduate organic chemistry course. *J. Res. Sci. Teach.* **2002,** *39* (7), 606-632.
107. Tien, L. T.; Roth, V.; Kampmeier, J. A., A Course To Prepare Peer Leaders To Implement a Student-Assisted Learning Method. *J. Chem. Educ.* **2004,** *81* (9), 1313.
108. National Research, C., *Education for life and work: Developing transferable knowledge and skills in the 21st century*. National Academies Press: 2012.
109. Etkina, E.; Van Heuvelen, A., Investigative science learning environment–A science process approach to learning physics. *Research-based reform of university physics* **2007,** *1* (1), 1-48.
110. Tanner, K. D., Promoting Student Metacognition. *CBE-Life Sci. Educ.* **2012,** *11* (2), 113-120.
111. Freeman, S.; Eddy, S. L.; McDonough, M.; Smith, M. K.; Okoroafor, N.; Jordt, H.; Wenderoth, M. P., Active learning increases student performance in science, engineering, and mathematics. *Proc. Natl. Acad. Sci. USA* **2014,** *111* (23), 8410.
112. Jaber, L. Z.; Hammer, D., Learning to feel like a scientist. *Sci. Educ.* **2016,** *100* (2), 189-220.
113. Eddy, S. L.; Brownell, S. E.; Wenderoth, M. P., Gender Gaps in Achievement and Participation in Multiple Introductory Biology Classrooms. *CBE-Life Sci. Educ.* **2014,** *13* (3), 478-492.
114. Otero, V.; Pollock, S.; Finkelstein, N., A physics department's role in preparing physics teachers: The Colorado learning assistant model. *Am. J. Phys.* **2010,** *78* (11), 1218-1224.
115. Kulatunga, U.; Lewis, J. E., Exploration of peer leader verbal behaviors as they intervene with small groups in college general chemistry. *Chem. Educ. Res. Pract.* **2013,** *14* (4), 576-588.
116. Smith, J.; Wilson, S. B.; Banks, J.; Zhu, L.; Varma-Nelson, P., Replicating Peer-Led Team Learning in cyberspace: Research, opportunities, and challenges. *J. Res. Sci. Teach.* **2014,** *51* (6), 714-740.
117. Chi, M. T. H.; Siler, S. A.; Jeong, H.; Yamauchi, T.; Hausmann, R. G., Learning from human tutoring. *Cognitive Science* **2001,** *25* (4), 471-533.
118. Eberlein, T.; Kampmeier, J.; Minderhout, V.; Moog, R. S.; Platt, T.; Varma-Nelson, P.; White, H. B., Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL*. *Biochem Mol Biol Educ* **2008,** *36* (4), 262-273.

119. Wilson, S. B.; Varma-Nelson, P., Characterization of First-Semester Organic Chemistry Peer-Led Team Learning and Cyber Peer-Led Team Learning Students' Use and Explanation of Electron-Pushing Formalism. *J. Chem. Educ.* **2019,** *96* (1), 25-34.
120. Close, E. W.; Conn, J.; Close, H. G., Becoming physics people: Development of integrated physics identity through the Learning Assistant experience. *Physical Review Physics Education Research* **2016,** *12* (1), 010109.
121. Solomon, J., Social Influences on the Construction of Pupils' Understanding of Science. *Studies in Science Education* **1987,** *14* (1), 63-82.
122. Bodner, G. M., Constructivism: A theory of knowledge. *J. Chem. Educ.* **1986,** *63* (10), 873.
123. Velasco, J. B.; Stains, M., Exploring the relationships between perceptions of tutoring and tutoring behaviours: a focus on graduate students serving as peer tutors to college-level chemistry students. *Chem. Educ. Res. Pract.* **2015,** *16* (4), 856-868.
124. Cole, R. S.; Becker, N.; Stanford, C., Discourse Analysis as a Tool To Examine Teaching and Learning in the Classroom. In *Tools of Chemistry Education Research*, American Chemical Society: 2014; Vol. 1166, pp 61-81.
125. Shultz, G. V.; Li, Y., Student Development of Information Literacy Skills during Problem-Based Organic Chemistry Laboratory Experiments. *J. Chem. Educ.* **2016,** *93* (3), 413-422.
126. Dohrn, S. W.; Dohn, N. B., The role of teacher questions in the chemistry classroom. *Chem. Educ. Res. Pract.* **2018,** *19* (1), 352-363.
127. Wells, G.; Arauz, R. M., Dialogue in the Classroom. *Journal of the Learning Sciences* **2006,** *15* (3), 379-428.
128. Scott, P. H.; Mortimer, E. F.; Aguiar, O. G., The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *J. Sci. Educ.* **2006,** *90* (4), 605-631.
129. O'Connor, C.; Michaels, S., When is dialogue 'dialogic'? *HD* **2007,** *50* (5), 275-285.
130. Graesser, A. C.; Person, N. K., Question Asking During Tutoring. *Am. Educ. Res. J.* **1994,** *31* (1), 104-137.
131. Buitink, J., What and how do student teachers learn during school-based teacher education. *Teaching Teach. Educ.* **2009,** *25* (1), 118-127.
132. Argyris, C., *Theory in practice : increasing professional effectiveness*. 1st ed. ed.; Jossey-Bass Publishers: San Francisco, 1974.
133. Wheeler, L.; Sturtevant, H.; Mumba, F., Exploratory Study of the Impact of a Teaching Methods Course for International Teaching Assistants in an Inquiry-Based General Chemistry Laboratory. *J. Chem. Educ.* **2019,** *96* (11), 2393-2402.
134. Knuth, E.; Peressini, D., Unpacking the nature of discourse in mathematics classrooms. *Mathematics Teaching in the Middle School* **2001,** *6* (5), 320-325.
135. Cook, E.; Kennedy, E.; McGuire, S. Y., Effect of Teaching Metacognitive Learning Strategies on Performance in General Chemistry Courses. *J. Chem. Educ.* **2013,** *90* (8), 961-967.
136. Krathwohl, D. R., A revision of Bloom's taxonomy: An overview. *Theor. Pract.* **2002,** *41* (4), 212-218.
137. Bunce, D. M.; Komperda, R.; Schroeder, M. J.; Dillner, D. K.; Lin, S.; Teichert, M. A.; Hartman, J. R., Differential Use of Study Approaches by Students of Different Achievement Levels. *J. Chem. Educ.* **2017,** *94* (10), 1415-1424.
138. Gellene, G. I.; Bentley, A. B., A Six-Year Study of the Effects of a Remedial Course in the Chemistry Curriculum. *J. Chem. Educ.* **2005,** *82* (1), 125-130.

139. Heredia, K.; Xu, X. Y.; Lewis, J. E., The application and evaluation of a two-concept diagnostic instrument with students entering college general chemistry. *Chem. Educ. Res. Pract.* **2012,** *13* (1), 30-38.
140. Donovan, W. J.; Wheland, E. R., Comparisons of success and retention in a general chemistry course before and after the adoption of a mathematics prerequisite. *School Sci. Math.* **2009,** *109* (7), 371-382.
141. Freeman, W. A., Relative long-term benefits of a PSI and a traditional-style remedial chemistry course. *J. Chem. Educ.* **1984,** *61* (7), 617.
142. Dockter, D.; Uvarov, C.; Guzman-Alvarez, A.; Molinaro, M., Improving preparation and persistence in undergraduate STEM: why an online summer preparatory chemistry course makes sense. In *Online Approaches to Chemical Education*, ACS Publications: 2017; pp 7-33.
143. Pickering, M., Helping the high risk freshman chemist. *J. Chem. Educ.* **1975,** *52* (8), 512-514.
144. Shields, S. P.; Hogrebe, M. C.; Spees, W. M.; Handlin, L. B.; Noelken, G. P.; Riley, J. M.; Frey, R. F., A Transition Program for Underprepared Students in General Chemistry: Diagnosis, Implementation, and Evaluation. *J. Chem. Educ.* **2012,** *89* (8), 995-1000.
145. Shah, L.; Butler Basner, E.; Ferraro, K.; Sajan, A.; Fatima, A.; Rushton, G. T., Diversifying Undergraduate Chemistry Course Pathways to Improve Outcomes for At-Risk Students. *J. Chem. Educ.* **2020,** *97* (7), 1822-1831.
146. Cox, C. T.; Poehlmann, J. S.; Ortega, C.; Lopez, J. C., Using Writing Assignments as an Intervention to Strengthen Acid–Base Skills. *J. Chem. Educ.* **2018,** *95* (8), 1276-1283.
147. Pyburn, D. T.; Pazicni, S.; Benassi, V. A.; Tappin, E. M., The Testing Effect: An Intervention on Behalf of Low-Skilled Comprehenders in General Chemistry. *J. Chem. Educ.* **2014,** *91* (12), 2045-2057.
148. Fink, A.; Cahill, M. J.; McDaniel, M. A.; Hoffman, A.; Frey, R. F., Improving general chemistry performance through a growth mindset intervention: selective effects on underrepresented minorities. *Chem. Educ. Res. Pract.* **2018,** *19* (3), 783-806.
149. Mills, P.; Sweeney, W.; Bonner, S. M., Using the First Exam for Student Placement in Beginning Chemistry Courses. *J. Chem. Educ.* **2009,** *86* (6), 738-743.
150. Harris, R. B.; Mack, M. R.; Bryant, J.; Theobald, E. J.; Freeman, S., Reducing achievement gaps in undergraduate general chemistry could lift underrepresented students into a “hyperpersistent zone”. *Science Advances* **2020,** *6* (24), eaaz5687.
151. Ye, L.; Shuniak, C.; Oueini, R.; Robert, J.; Lewis, S., Can they succeed? Exploring at-risk students' study habits in college general chemistry. *Chem. Educ. Res. Pract.* **2016,** *17* (4), 878-892.
152. Crisp, G.; Nora, A.; Taggart, A., Student Characteristics, Pre-College, College, and Environmental Factors as Predictors of Majoring in and Earning a STEM Degree: An Analysis of Students Attending a Hispanic Serving Institution. *Am. Educ. Res. J.* **2009,** *46* (4), 924-942.
153. Tai, R. H.; Sadler, P. M.; Loehr, J. F., Factors influencing success in introductory college chemistry. *J. Res. Sci. Teach.* **2005,** *42* (9), 987-1012.
154. Griffith, A. L., Persistence of women and minorities in STEM field majors: Is it the school that matters? *Econ. Educ. Rev.* **2010,** *29* (6), 911-922.
155. Shaw, E.; Barbuti, S., Patterns of Persistence in Intended College Major with a Focus on STEM Majors. *NACADA J.* **2010,** *30*.
156. Legg, J. C.; Greenbowe, T. J.; Legg, M. J., Analysis of Success in General Chemistry Based on Diagnostic Testing Using Logistic Regression. *J. Chem. Educ.* **2001,** *78* (8), 1117.

157. Hovey, N. W.; Krohn, A., An evaluation of the Toledo chemistry placement examination. *J. Chem. Educ.* **1963,** *40* (7), 370-372.
158. Ye, L.; Oueini, R.; Dickerson, A. P.; Lewis, S. E., Learning beyond the classroom: using text messages to measure general chemistry students' study habits. *Chem. Educ. Res. Pract.* **2015,** *16* (4), 869-878.
159. Tait, H.; Entwistle, N.; McCune, V., ASSIST: A reconceptualisation of the approaches to studying inventory. In *Improving Students as Learners*, Rust, C., Ed. Oxford Brooks University, Oxford Centre for Staff and Learning Development: Oxford, 1998; pp 262-271.
160. Entwistle, N.; McCune, V.; Tait, H. Approaches and study skills inventory for students (ASSIST): Report of the development and use of the inventories. Retrieved from: http://www.researchgate.net/publication/260291730_Approaches_and_Study_Skills_Inventory_for_Students_(ASSIST)_.
161. Akaike, H., A new look at the statistical model identification. *IEEE T. Automat. Contr.* **1974,** *19* (6), 716-723.
162. Burnham, K. P.; Anderson, D. R., Multimodel Inference: Understanding AIC and BIC in Model Selection. *Sociol. Method. Res.* **2004,** *33* (2), 261-304.
163. Fink, A.; Frey, R. F.; Solomon, E. D., Belonging in general chemistry predicts first-year undergraduates' performance and attrition. *Chem. Educ. Res. Pract.* **2020**.
164. Entwistle, N.; Tait, H.; McCune, V., Patterns of response to an approaches to studying inventory across contrasting groups and contexts. *Eur. J. Psychol. Educ.* **2000,** *15* (1), 33-48.
165. Meyer, J. H. F., The modelling of 'dissonant' study orchestration in higher education. *Eur. J. Psychol. Educ.* **2000,** *15* (1), 5-18.
166. Meyer, J. H. F., Study Orchestration: The Manifestation, Interpretation and Consequences of Contextualised Approaches to Studying. *High. Educ.* **1991,** *22* (3), 297-316.
167. Lindblom-Ylänne, S.; Lonka, K., Dissonant study orchestrations of high-achieving university students. *Eur. J. Psychol. Educ.* **2000,** *15* (1), 19-32.
168. Rickey, D.; Stacy, A. M., The Role of Metacognition in Learning Chemistry. *J. Chem. Educ.* **2000,** *77* (7), 915.
169. Kruger, J.; Dunning, D., Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments. *J. Pers. Soc. Psychol.* **1999,** *77* (6), 1121-1134.
170. Pintrich, P. R., The Role of Metacognitive Knowledge in Learning, Teaching, and Assessing. *Theor. Pract.* **2002,** *41* (4), 219-225.
171. MacPhee, D.; Farro, S.; Canetto, S. S., Academic Self-Efficacy and Performance of Underrepresented STEM Majors: Gender, Ethnic, and Social Class Patterns. *Anal. Soc. Iss. Pub. Pol.* **2013,** *13* (1), 347-369.
172. Wagner, E. P.; Sasser, H.; DiBiase, W. J., Predicting Students at Risk in General Chemistry Using Pre-semester Assessments and Demographic Information. *J. Chem. Educ.* **2002,** *79* (6), 749.
173. Means, B.; Toyama, Y.; Murphy, R.; Bakia, M.; Jones, K. *Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies*; U.S. Department of Education: Washington, D.C., 2009.
174. Szpunar, K. K.; Jing, H. G.; Schacter, D. L., Overcoming overconfidence in learning from video-recorded lectures: Implications of interpolated testing for online education. *J. Appl. Res. Mem. Cogn.* **2014,** *3* (3), 161-164.
175. Schacter, D. L.; Szpunar, K. K., Enhancing attention and memory during video-recorded lectures. *Scholarsh. Teach. Learn. Psychol.* **2015,** *1* (1), 60-71.

176. Finn, B.; Tauber, S. K., When Confidence Is Not a Signal of Knowing: How Students' Experiences and Beliefs About Processing Fluency Can Lead to Miscalibrated Confidence. *Educ. Psychol. Rev.* **2015,** *27* (4), 567-586.
177. Mutambuki, J. M.; Mwavita, M.; Muteti, C. Z.; Jacob, B. I.; Mohanty, S., Metacognition and Active Learning Combination Reveals Better Performance on Cognitively Demanding General Chemistry Concepts than Active Learning Alone. *J. Chem. Educ.* **2020,** *97* (7), 1832-1840.
178. Ee, J.; Moore, P. J.; Atputhasamy, L., High-achieving Students: Their motivational goals, self-regulation and achievement and relationships to their teachers' goals and strategy-based instruction. *High Abil. Stud.* **2003,** *14* (1), 23-39.
179. Petillion, R. J.; McNeil, W. S., Johnstone's Triangle as a Pedagogical Framework for Flipped-Class Instructional Videos in Introductory Chemistry. *J. Chem. Educ.* **2020,** *97* (6), 1536-1542.
180. Brame, C. J., Effective Educational Videos: Principles and Guidelines for Maximizing Student Learning from Video Content. *CBE-Life Sci. Educ.* **2016,** *15* (4), es6-es6.6.
181. Urban, S.; Brkljača, R.; Cockman, R.; Rook, T., Contextualizing Learning Chemistry in First-Year Undergraduate Programs: Engaging Industry-Based Videos with Real-Time Quizzing. *J. Chem. Educ.* **2017,** *94* (7), 873-878.
182. Flower, D.; James, M. L., *Small Teaching Online : Applying Learning Science in Online Classes*. 1 ed.; Jossey-Bass: San Francisco, CA, 2019.
183. Amaral, K. E.; Shank, J. D.; Shibley, I. A.; Shibley, L. R., Web-Enhanced General Chemistry Increases Student Completion Rates, Success, and Satisfaction. *J. Chem. Educ.* **2013,** *90* (3), 296-302.
184. Reardon, R. F.; Traverse, M. A.; Feakes, D. A.; Gibbs, K. A.; Rohde, R. E., Discovering the Determinants of Chemistry Course Perceptions in Undergraduate Students. *J. Chem. Educ.* **2010,** *87* (6), 643-646.
185. O'Neal, C.; Wright, M.; Cook, C.; Perorazio, T.; Purkiss, J., The impact of teaching assistants on student retention in the sciences: Lessons for TA training. *J. Coll. Sci. Teach.* **2007,** *36* (5), 24.
186. National Science Board. 2014. *Science and Engineering Indicators 2014.* NSB-2014-01. Alexandria, VA: National Science Foundation. Retrieved from https://www.nsf.gov/statistics/seind14/ (Accessed 11/15/2015).
187. Gasiewski, J. A.; Eagan, M. K.; Garcia, G. A.; Hurtado, S.; Chang, M. J., From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Res. High. Educ.* **2012,** *53* (2), 229-261.
188. Shedlosky-Shoemaker, R.; Fautch, J. M., Who Leaves, Who Stays? Psychological Predictors of Undergraduate Chemistry Students' Persistence. *J. Chem. Educ.* **2015,** *92* (3), 408-414.
189. Serra, M. J.; Metcalfe, J. *Effective implementation of metacognition*, Routledge/Taylor & Francis Group: New York, NY, US, 2009.
190. Parker Siburt, C. J.; Bissell, A. N.; Macphail, R. A., Developing Metacognitive and Problem-Solving Skills through Problem Manipulation. *J. Chem. Educ.* **2011,** *88* (11), 1489-1495.
191. Sandi-Urena, S.; Cooper, M.; Stevens, R., Effect of Cooperative Problem-Based Lab Instruction on Metacognition and Problem-Solving Skills. *J. Chem. Educ.* **2012,** *89* (6), 700-706.
192. Pungente, M. D.; Badger, R. A., Teaching Introductory Organic Chemistry: 'Blooming' beyond a Simple Taxonomy. *J. Chem. Educ.* **2003,** *80* (7), 779.
193. Rosenshine, B.; Meister, C., The use of scaffolds for teaching higher-level cognitive strategies. *Educ. Leadership* **1992,** *49* (7), 26-33.
194. Zimmerman, B. J., Self-regulated learning and academic achievement: An overview. *Educ. Psychol.* **1990,** *25* (1), 3-17.

195. Gulacar, O.; Eilks, I.; Bowman, C. R., Differences in General Cognitive Abilities and Domain-Specific Skills of Higher- and Lower-Achieving Students in Stoichiometry. *J. Chem. Educ.* **2014,** *91* (7), 961-968.
196. Weaver, G.; Green, K.; Rahman, A.; Epp, E., An Investigation of Online and Face-to-Face Communication in General Chemistry. *International Journal for the Scholarship of Teaching and Learning* **2009,** *3*.
197. Gosser, D. K.; Cracolice, M. S.; Kampmeier, J. A.; Roth, V.; Strozak, V.; Varma-Nelson, P., *Peer-led team learning: A guidebook*. Prentice Hall: Upper Saddle River, NJ, 2001.
198. Tan, S.-C.; Seah, L.-H., Exploring relationship between students' questioning behaviors and inquiry tasks in an online forum through analysis of ideational function of questions. *Comput. Educ.* **2011,** *57* (2), 1675-1685.
199. Mohamad, M.; Shaharuddin, S., Online forum discussion to promote sense of learning community among the group members. *Int. Educ. Studies* **2014,** *7* (13), 61.
200. Thoms, B.; Eryilmaz, E., Introducing a twitter discussion board to support learning in online and blended learning environments. *Education and Information Technologies* **2013,** *20*.
201. Kang, M.; Shin, W. s., An Empirical Investigation of Student Acceptance of Synchronous E-Learning in an Online University. *J. Educ. Comput. Res.* **2015,** *52* (4), 475-495.
202. McBrien, J.; Rui, C.; Jones, P., Virtual Spaces: Employing a Synchronous Online Classroom to Facilitate Student Engagement in Online Learning. *International Review of Research in Open and Distance Learning* **2009,** *10*, 1-17.