

Give and Take: Narrowing the Gap between Theory and Practice of Peer Instructors over Time

Emily L. Atieh* and Darrin M. York*

Cite This: *J. Chem. Educ.* 2022, 99, 3370–3385

Read Online

ACCESS |



Metrics & More



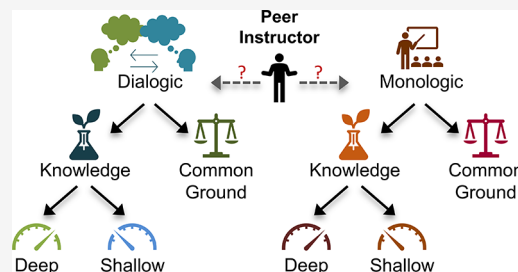
Article Recommendations



Supporting Information

ABSTRACT: With the rise in implementation of peer-led learning in higher education, the interactions between peer instructors and their students warrant further investigation as an increasingly critical component of student learning. In this work, Teaching Interns (TIs) are undergraduate peer instructors that lead supplemental learning sessions in General Chemistry. Each week, TIs participate in pedagogy training and complete written reflections on their learning sessions. For this multicase study, six TIs were observed in their office hours over varying time periods. A qualitative approach was taken to analyze their verbal behaviors and the extent to which those behaviors matched their beliefs about teaching. Specifically, discourse analysis allowed for the characterization of the interactions between TIs and students, while analysis of TIs' weekly written reflections provided insight into their teaching beliefs and perception of their own teaching sessions. The results presented here suggest that even at the start of the program, TIs hold some productive beliefs about teaching, though these beliefs were not always evident in their interactions with students. Over time, TIs generally shifted toward more student-centered discourse and honed their abilities to convey or elicit deeper knowledge among their students. Further, evidence from the TIs' reflections suggest that they became better at self-monitoring their own teaching behaviors, shrinking the gap between their practices and espoused beliefs about teaching, and that they turned their focus toward student learning versus simply managing their sessions. Taken together, this work provides additional support for the further development and study of peer instruction programs.

KEYWORDS: First-Year Undergraduate/General, Collaborative/Cooperative Learning, Professional Development, Constructivism, Student-Centered Learning, TA Training/Orientation



INTRODUCTION

As institutions of higher education seek to make their classrooms more conducive to active learning, peer instruction has been an increasingly important type of reform to facilitate this process. Within peer instruction, undergraduate student learning is facilitated by other undergraduates that usually have demonstrated prior success in the same course, and in some cases have also had pedagogical training in instruction. There is an extensive literature on the benefits of peer instruction for students on the receiving end,^{1–3} as well as for the peer instructors themselves.^{4–7} 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 Lewis⁸ 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 colleagues⁹ investigated the differences between peer instructors' behaviors within a traditional Peer-Led Team Learning (PLTL) settings versus its cyber counterpart (cPLTL). However, it remains

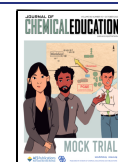
unclear as to how the modes of interaction of peer instructors change over time, how their training is tied to those changes, and whether or not the peer instructors are cognizant of those changes.

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.^{4,10} 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. 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,^{11,12} and in most cases, they receive training in how to conduct their learning sessions, unlike the many tutors.¹³ For example, a multiple-case study by Velasco

Received: February 22, 2022

Revised: August 11, 2022

Published: September 12, 2022



and Stains identified a connection between chemistry tutors' perceptions of their tutoring and their actual tutor behaviors, as measured by interviews and observations, respectively.¹⁴ In their study, the tutors operated independently (i.e., not as part of a larger tutoring program) and, as is typical, had not received any type of pedagogical training. As such, peer instructors afford an opportunity to examine an important middle ground population that also represents a key element of teaching and learning infrastructure at many universities, including Rutgers.

By employing a similar analytic approach as Velasco and Stains to this population, this work seeks to understand how the theory–practice gap evolves over time as the TIs undergo pedagogical training and gain experience as part of a formal peer instruction program. A multicase 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 its relation to social constructivism, as well as a look at how discourse analysis has been used to characterize classroom dynamics in the literature. Practical theory was selected as a framework to formulate and guide the three research questions. 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,¹⁵ has grown tremendously since the early days of Supplemental Instruction (SI).¹⁶ Countless other models have since been implemented and reported on in the literature, spanning a variety of disciplines (chemistry,^{4,17} nursing,¹⁸ computer science,¹⁹ sociology,²⁰ etc.) and program structures. There is no singular peer instruction program model, and so they often vary widely in their structure and training mechanism. For example, in Peer-Led Team Learning (PLTL), groups of 6–8 students gather on a regular (e.g., weekly) basis to work on a predetermined assignment while the peer leader, a former student in the class that has undergone PLTL training, facilitates discussion.^{21,22} On the other end of the spectrum, peer tutoring is generally a much less structured one-on-one environment, often without prepared assignments or tutor training, and may be arranged formally, such as through a university learning center, or privately between individuals.¹³

One guiding principle for many of these programs is social constructivism and the practice of facilitating knowledge through scaffolding.^{23–25} 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.^{26–28} As Murphey describes near

peers as those close in age and social level,¹⁵ it is fitting that a constructivist framework underlies these peer instruction programs, as students are able to coconstruct knowledge with those of a similar level and background. However, as Velasco and Stains discuss,¹⁴ 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.^{4,10} This program is a peer instruction model in which former, successful General Chemistry students assist current General Chemistry students through various types of supplemental instructional sessions. Like PLTL leaders and Learning Assistants,²⁹ the TIs receive weekly pedagogy and best practices training. However, the setting for this study is a General Chemistry office hour—a relatively unstructured environment that often involves more one-on-one facilitation, akin to a tutoring session. 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 tacit forms of communication within a defined setting.³⁰ 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 Li³¹ 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,³² 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 a 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.³³ Conversely, dialogic discourse invites equal participation from all parties, usually in the context of coconstructing learning.³³ Similar schemes have been used previously, such as interactive versus noninteractive discourse.³⁴ 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.³⁵ In their work, they explain how episodes of dialogue can take on mixed ideological and structural forms. For example, a teacher asking questions to a student 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. For the purposes of this study, it is critical to note that the model of peer instruction asserts that the peer instructors are not intended to be authority figures or content knowledge experts, but rather similar to the age and professional/social status of the learner (notably this may not be the case at all institutions, such as community colleges that host a wider population of nontraditional students).³⁶ Further, in the TI model, the TIs themselves have neither access to nor authority over students' grades. Thus, with these assumptions, 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 Dohn³² characterize the various questions posed by chemistry teachers according to content (e.g., academic) and function (e.g., clarification). In the context of a tutoring session, Velasco and Stains¹⁴ classify the type of information exchanged as "knowledge" or "common ground". This classification aligns with Wells and Arauz,³³ 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 the TI-led office hour, it was helpful to use this same scheme to differentiate the exchange of new information from these instances of negotiated understanding. Thus, the second dimension of discourse was broken down into "knowledge" versus "common ground".

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 Stains¹⁴ further divided their knowledge category into knowledge-telling behaviors and knowledge-building behaviors, (common ground codes were not differentiated in this way). Similarly, Graesser and Person³⁷ 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. An amalgam of these approaches was 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.³⁸ This is in contrast to the teaching practices for which an instructor may verbally advocate, which may or may not be aligned with their practical theory. Argyris and Schön use the term congruence to describe the alignment of one's "theory-in-practice" (what they actually do) with their "espoused theory" (what they claim to do).³⁹ Using this framework, Jaap Buitink³⁸ 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 Stains¹⁴ 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 remarkably 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. Moreover, 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.^{21,40} Much of the TIs' training stems from the ideas associated with Meaningful Learning Theory and neuronal networks. David Ausubel writes that meaningful learning occurs when new information is purposefully linked to a person's prior knowledge.⁴¹ This means, at the very least, an instructor must accept that all students have unique experiences that shape their prior knowledge (i.e., they are not "blank slates"), and they must find ways to access that knowledge. James E. Zull brings in a tangible component to this discussion, referring to networks of neurons and synapses that fire and strengthen (or weaken) with experience and thus shape a person's knowledge construction.⁴² Both of these models are introduced to the TIs early on and shape the way other training topics, such as analogies and alternate conceptions, are approached. Thus, the TIs' espoused theories, and perhaps practical theories, were expected to be influenced by these ideas during their time in the program.

This study uses observations to characterize TIs' practices, coupled with their written reflections to expand upon their practices and 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 TI, and how that relates to their own perception of their teaching practices. The three research questions (RQs) are as follows:

1. To what extent do peer instructors' use of monologic and dialogic verbal behaviors change over time? (Dimension #1)
2. To what extent does the content of the interactions between peer instructors and their students change over time? (Dimensions #2 and #3)
3. To what extent does the alignment between a peer instructor's teaching beliefs and their actual teaching behaviors change over time?

■ 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 to five different instructors each semester, but all students complete common exams, quizzes, and online homework. In addition to lectures, all students attend a weekly recitation. Each week, the TIs hold numerous supplemental help sessions such as office hours and workshops.

The Teaching Interns

At Rutgers, the undergraduate Certificate in Chemistry Education (CCE) program was founded in 2015.⁴³ This nine-credit program includes a Pedagogy Course and teaching experience for both the General Chemistry courses (via the Teaching Internship) and the laboratory (Table 1). Addition-

Table 1. Certificate in Chemistry Education (CCE) Coursework and Requirements⁴⁴

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

⁴⁴Reproduced from Atieh et al.⁴

ally, undergraduate students can become involved in the Teaching Internship separately, without earning the certificate.¹⁰ Students are invited to apply and interview for either the CCE program or the Teaching Internship based on their success in General Chemistry, though an “A” in the course is not required. Approximately 15 students are selected to enroll in the Pedagogy Course and 40–50 in the Teaching Internship each semester. In a given semester, nearly half of the TIs are returning (second- or third-year TIs).

Students in the Pedagogy Course (“CCE-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. As part of the course, they also held one office hour per week for General Chemistry. While those in the Teaching Internship also receive weekly training in the form of staff meetings, it is primarily focused on best practices, such as ways to get students to work together, how to construct effective questions, and how to scaffold learning. They hold approximately two learning sessions per week, in the form of office hours, workshops, or as recitation facilitators. For the duration of this study, one author (E.L.A.) was the instructor for both the Pedagogy Course and the TI staff meetings, and coordinated the CCE program.

METHODS

Observations

Observations of six TIs in their office hours were conducted over four semesters, spanning Fall 2017 to Spring 2019. Broadly

speaking, a TI’s role during office hours is to assist the students with the questions they bring. Students are not given any particular guidelines for how to utilize office hours, and some choose to bring specific problems to tackle, such as incorrect items from their old exams, while others have only general or vague ideas of the difficulties they would like to address. Office hours were selected as the target for observations for several factors. First, office hours are unstructured in that TIs are not expected to prepare any formal activity or lesson (as would be the case in a workshop), and students typically attend with their own individual purposes in mind (as opposed to a recitation). Thus, it was expected that the TI-student interactions would be more organic, centered around actual student difficulties and less bound to a single topic. Second, office hours were more accessible to students, as they were held during a six-hour block every weekday and students could come as they pleased, as opposed to workshops, for which students needed to sign up ahead of time. Greater accessibility would hopefully lead to a greater diversity of students. Lastly, office hours were more conducive to observations, as the TIs remained in the same general location, enabling extended conversations with students, rather than moving around the room such as during a recitation.

The six TIs in this study were each observed in office hours 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 largely due to convenience. Most second- and third-year TIs move on to holding more “senior” type learning sessions (e.g., workshops, recitations), so opportunities to observe the same TI over extended periods of time in their office hours were limited. Further, there was a number of instances in which the office hour attendees (General Chemistry students) did not consent to participate in the study and thus that particular TI was unable to be recorded during the necessary weeks of data collection. More logistical obstacles, such as audio quality on a particularly busy day, were a minor factor. Of the TIs who fit the longitudinal criteria and whose observations were suitably recorded ($N = 12$), the selection of the final six attempted to control for gender and whether or not the TI enrolled in the Pedagogy Course, where possible. When all factors were equal, the final selection was made by random choice.

The room in which office hours are conducted is a large, open room full of tables and serves as a popular campus study space. The TIs have two large tables and a white board reserved for 6 h each weekday, with one TI per hour, and students may drop in at any time. Typical attendance is 3–5 students at any given time, though 10–12 students at once is not uncommon during exam weeks. Video data collection was not suitable due to (1) being a shared room and (2) the possibility of being a deterrent for students seeking help. Instead, audio data was collected and the observer (E.L.A.) took notes of nonverbal behaviors and other details.

Audio data was transcribed verbatim with timestamps by the author (E.L.A.) using NVivo 11. A sampling technique was used to analyze the data in part because of the challenges described above; for example, having a mixture of students who did and did not consent to be recorded in a single office hour meant only portions of an office hour could be collected. To allow the TI to acclimate to the observation, the first five minutes are excluded from analysis. Afterward, the next ten minutes and the final ten minutes are coded. If extraordinary differences between the two sets of data arose, a contingency plan was put into place such that

Three Dimensions of Discourse			
I. Direction	II. Type	III. Depth	Example (TI dialogue)
Dialogic 	Knowledge 	Deep 	What's something you can determine 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.
None/Noninteractive 			[TI solves a problem on their own, without demonstrating to the student]
Student-Doing 			[Student is speaking or working]

Figure 1. Hierarchy of the three dimensions of discourse used to describe TI office hours.

an additional five minutes of data would be analyzed; however, after initial coding, the researchers independently agreed that this extra step was not necessary.

Analysis of Transcripts

Cole et al. state that the selection of a unit of analysis is a key step in discourse studies.³⁰ Units of analysis are the individual portions that are coded and may be 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” proved to be subjective. Using the turns of speech as a unit had the potential to mislead as well, as 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 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 finer grain (e.g., asking a recall question, giving course advice). This coding scheme was organized and placed into a spreadsheet with examples for training. The second researcher coded approximately 15% of the data chosen at random from each TI. The initial overall agreement was 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 S9](#) along with examples of each.

As described in the [Background](#) of this paper, discourse was analyzed using three different dimensions ([Figure 1](#)).

The first dimension of discourse (direction) sought to address RQ1, determining whether TIs adjusted their speech to encourage information to flow both ways or if they predominantly spoke at the student. Discourse was classified as “monologic” if the information given by the TI to the student was strictly intended to deliver a specific message.⁴⁴ Discourse was coded as “dialogic” if the TI was actively eliciting 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 (type) used to analyze the data is based on the type of information being communicated and partially addressed RQ2. 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 other type 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 the final dimension (depth). For monologic discourse, a distinction was made when TIs included detailed reasoning (deep) versus no reasoning (shallow) when providing knowledge. For dialogic discourse, questions posed by the TIs were classified under one of 16 types described by Graesser and Person.³⁷ The required length of response³⁷ and number of possible answers were used to categorize knowledge questions as deep or shallow: questions requiring both longer answers and for which there were multiple possible answers were classified as deep, while shallow questions met one or neither of these requirements. Examples of these question types can be found in [Table 2](#), and the full list of all 16 question types is provided in the [Supporting Information](#) (Table S10).

Written Reflections

Each week, TIs submit their written reflection to a forum on the course management Web site. Reflections are semiguided and generally include open-ended questions about their takeaways from their learning sessions and weekly training (or Pedagogy Course). A sample prompt can be found in the [Supporting Information](#). Reflection posts were analyzed for each TI in this study, primarily focusing on the ways TIs describe their roles, teaching beliefs, and personal changes that they perceive.

IRB

All methods and procedures discussed herein were granted IRB approval under protocol #15-813M with annual renewal. All participants in this study, including General Chemistry students, provided their informed consent.

Table 2. Classification of TI Question Types

Question Type ^a	Length of Response	Number of Possible Correct Responses	Depth	Example from Observations
Verification	Short	Single	Shallow	<i>Do you need the mass of the electron?</i>
Feature specification	Short	Single	Shallow	<i>What column is calcium in?</i>
Definition	Long	Single	Shallow	<i>What is the Heisenberg Uncertainty Principle?</i>
Example	Long	Multiple	Deep	<i>Can you give me an example of when this equilibrium would shift the other way?</i>
Enablement	Long	Multiple	Deep	<i>So what will help us determine the order of this reaction?</i>

^aQuestion types adapted from Graesser and Person.³⁷ A complete list of the 16 question types can be found in the [Supporting Information](#) (Table S10).

ONE SEMESTER: CHARLIE AND THEO

Charlie and Theo both began in the Fall 2017 semester as TIs, though Theo was enrolled in the Pedagogy Course, while Charlie was not. As detailed below, both TIs began their respective programs with similar discourse profiles and make comparable transformations over the course of the semester (Figure 2, Table 3). Though their training was slightly different, both TIs discussed the pedagogical knowledge they gained and how they applied such knowledge when working with their students.

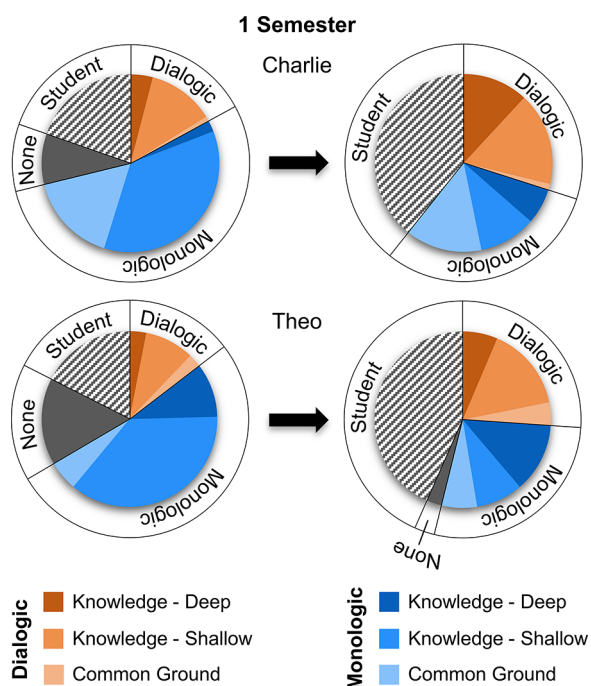


Figure 2. Pie charts illustrate the breakdown of discourse type for Charlie (top) and Theo (bottom) in their first observations (left) and their second observations conducted 1 semester later (right). TI verbal behaviors were classified as “dialogic” or “monologic”. Instances in which the students were speaking or working are labeled “Student”, while noninteractive time spent is labeled “None”.

Table 3. Number of Questions Posed by TIs in Their First and Second Observations

Question Type	Charlie		Theo	
	1st	2nd	1st	2nd
Low Level	9	16	10	18
High Level	5	13	3	9
Total	14	29	13	27

Charlie

At the very beginning of the TI program, Charlie described his overall teaching strategy as one who guides their student into understanding (Figure 3). It is unclear how he defines the word “guide”, but he seems to value students’ conceptual understanding via his words “understand what the formulas mean”. Discourse analysis of his first observation shows that more than 50% of his time is spent utilizing monologic discourse—largely shallow knowledge-telling (Figure 2). Regarding his dialogic discourse, Charlie asked 14 questions to his student, of which approximately two-thirds were classified as low-level (Table 3), and he spent nearly 10% of his time thinking to himself or solving a problem without interacting with the student. That week, Charlie wrote that during his observed office hour, he was confident in his ability to answer students’ questions effectively and felt that his approach to problem-solving was “more organized and understandable” than the students’ approach. While his reflection also indicates that he values assessing student understanding (via practice questions), this was not something he was able to prioritize or practically achieve.

After the next week of office hours (Week 3), Charlie seemed to recognize that he was doing too much explaining and instead should have allowed the students to initiate the problem-solving. Notably, that week’s training covered the topic of Meaningful Learning Theory, where TIs engaged in activities that encouraged them to consider the unique knowledge connections (“neuronal networks”) that each student brings. For the following weeks, Charlie’s takeaways from the weekly meetings centered around gaining access to his students’ knowledge and thought processes. For example, in Weeks 5 and 7, Charlie seems to invoke the neuronal network model from training, stating that by uncovering students’ knowledge connections and reasoning, he feels he can improve their conceptual understanding.

During Week 8, the TIs had a chance to practice (and model) their office hours with their fellow TIs acting as students. This week did not introduce any new training material, so this provided an opportunity to see what teaching practices TIs noticed (and perhaps valued) from their colleagues, many of whom had at least a year of prior TI experience. Charlie picked up on the fact that other TIs used a scaffolded approach with their questioning in order to negotiate understanding between the TI and “students”, and stated that it was something he might be interested in trying. This seems fitting with a recurring theme in Charlie’s reflections regarding accessing and assessing students’ understanding.

In Charlie’s second observation (Week 14), there were several notable changes compared to his first. The proportion of time spent engaging in dialogic discourse increased, while that of monologic discourse decreased and within both, the relative percentages of shallow knowledge decreased (Figure 2). With that, the number of questions he asked doubled to 29, with 13 of them being high-level questions, representing a larger proportion than his first observation. Accordingly, the amount

Teaching and Learning Sessions:

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

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

I began to guide the students in how to solve the problem too much...I would essentially set up an equation and just explain what I was doing and why...it would be more effective to have the student think harder as to how to start off a problem.

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

Week 1
Intro, course norms

Week 2*
Cooperative Learning

Week 3
Meaningful learning (I)

Week 4
Effective questioning

Week 5
Meaningful learning (II)

Week 6
Study habits, self-monitoring

Week 7
Alternate Conceptions

Week 8
"Roleplay" office hours

Week 9
Difficult scenarios

Week 10
Student differences

Week 11
Analogies

Week 13
Scaffolding

Week 14*
Wrap-up, reflection

Weekly Meeting Training:

...incorporate more open ended questions because they are better for gauging a student's understanding of the material.

...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, then it should help them grasp certain concepts quicker and with more comprehension.

...to try and figure out why a student took a certain approach about solving a problem. By doing this, you are able to correct the issue from the roots of the problem

...many [TIs] asked a lot of preliminary questions before even starting the question to ensure that the student understood the idea behind the problem. It seems like something I might want to spend more time on...

For each weekly meeting I was able to take away some useful bit of information on how to teach better,...become a more effective communicator...Things I applied to my learning sessions included: not always saying a student's approach is "wrong" and [just] offering a better approach, frequently asking questions as I help a student to ensure they are following along, trying to make each problem "our" problem, being confident, and trying to make analogies to simplify material when possible.

Figure 3. Excerpts from Charlie's reflection posts throughout the semester. The middle column lists the topic for that week's training, with the darker text representing the weeks from which reflections are presented here. Asterisks (*) denote the weeks of observations. Quotes on the left side are in response to the reflection prompts concerning teaching and TIs' learning sessions, while quotes on the right side address the TIs' "takeaway" messages from their weekly training. See the [Supporting Information](#) for an example of a reflection prompt.

of active student time doubled, and there was no evidence of noninteractive time. Looking toward his reflection from that week (Week 14), which included an overall reflection of the semester as well, Charlie acknowledged that his teaching practices have shifted to a more student-centered approach, giving the student more space to work through a problem rather than jumping into explanations. Charlie frames this as a benefit for his own teaching, as this strategy helps to identify student difficulties and monitor their understanding, reminiscent of his Week 4 reflection.

Charlie's final reflection suggests that some of his transformation may be attributed to the training, stating that the meetings helped him to develop his communication skills and provided the knowledge needed for asking questions, approaching students' misconceptions, and using analogies. One specific tie back to the weekly meetings is Charlie's effort to use the word "our", as in "make each problem "our" problem". This approach was emphasized by the instructor (E.L.A.) during the second week's meeting, as a strategy to build trust and mutual responsibility between the TI and their students.

Overall, Charlie began and ended the semester by using the word "guide" to describe his teaching strategies, despite the fact that his observations paint two different pictures of teaching. While his reflections generally mirror the trends gleaned from the discourse analysis, there are some exceptions worth considering. For example, Charlie did not change the amount of time spent establishing common ground with his students, which may have been expected given his focus on arriving at mutual understanding in his reflections. Nevertheless, it would appear that his beliefs about teaching (espoused theories) were more aligned to his actual practice at the end of the semester, compared to the beginning.

Theo

In Theo's first reflection post, he states that he does not want to "lead" his students but will "redirect" them if they are having difficulties (Figure 4). Similar to Charlie's second reflection, Theo concludes by saying that he wants to learn how to get his own thinking across to students. In fact, the two had several remarkable similarities when they first began the program. Just

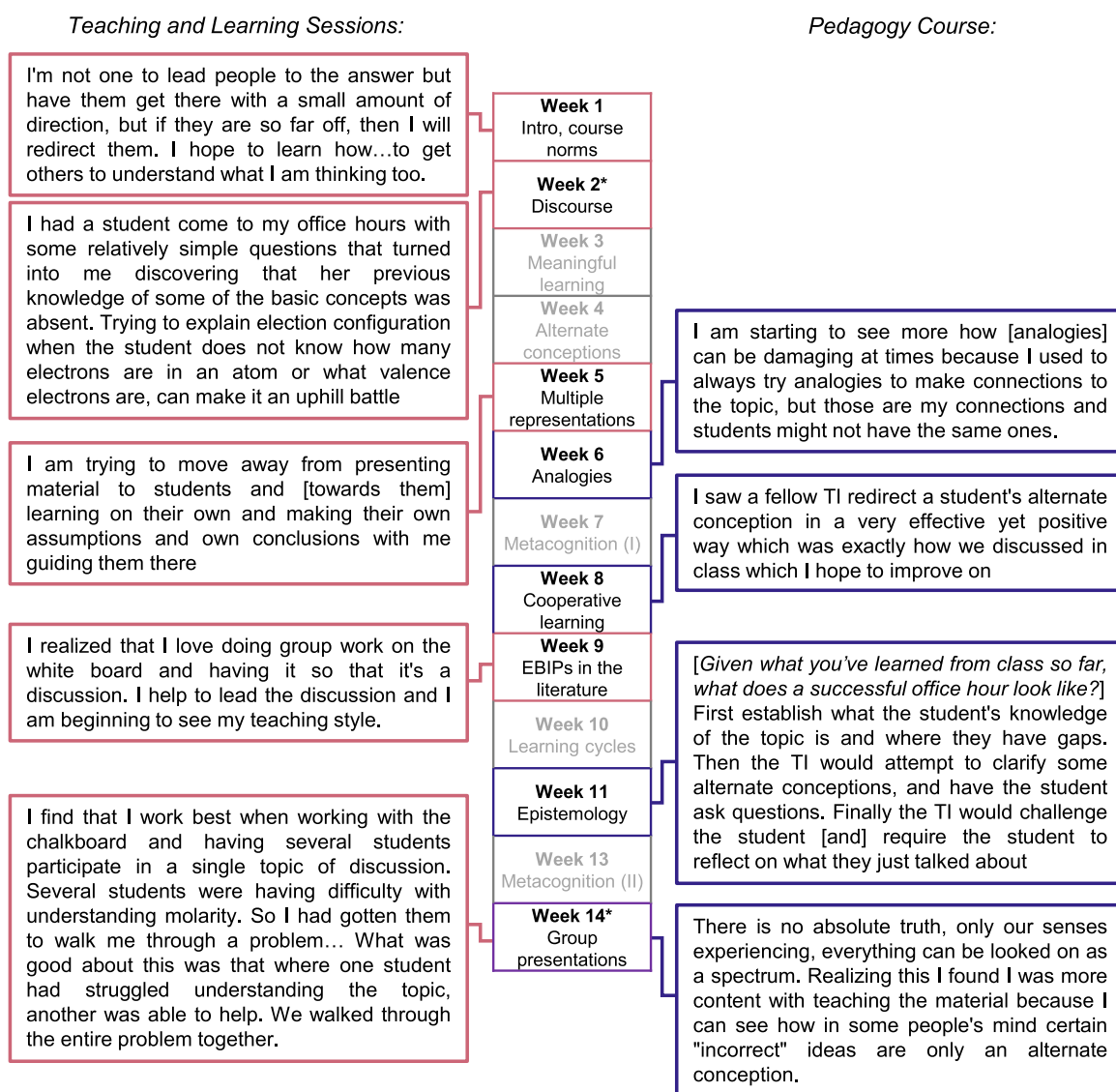


Figure 4. Excerpts from Theo's reflection posts throughout the semester. The middle column lists the topic for that week's Pedagogy Course, with the darker text representing the weeks from which reflections are presented here. Asterisks (*) denote the weeks of observations. Quotes on the left side are in response to the reflection prompts concerning teaching and TIs' learning sessions, while quotes on the right side address the TIs' "takeaway" messages from class. See the [Supporting Information](#) for an example of a reflection prompt.

over half of Theo's discourse in the first observation was monologic in nature, with the bulk of that being in the form of shallow knowledge (Figure 2). Regarding his dialogic discourse, Theo asked 13 questions and over two-thirds were low-level (Table 3). However, unlike Charlie, Theo spent near equal amount of time working on the problems individually (i.e., noninteractive) as the student did working or speaking. When writing about this particular week, Theo used his reflection space to describe one challenge that arose when his expectations of a student did not align with reality. He found that while he tried to "explain" electron configurations, she lacked some of the foundational pieces of knowledge. This matches the predominance of monologic discourse observed and the limited student dialogue illustrated in Figure 2, and suggests that Theo was aware that he relied mainly on explanations to exchange knowledge. It is possible that this is the type of scenario he referred to when using the word "redirect" in his first reflection.

During Week 8, TIs in the Pedagogy Course were tasked with observing another TI's office hours as part of a graded

assignment. One strategy that caught Theo's attention was the way another TI handled a student's alternate conceptions, a course topic that had been covered in Week 4, which he alluded to again in Weeks 11 and 14. It is noteworthy that he discusses this concept multiple times throughout the semester, weeks after it was covered in class. Theo also frequently invoked his knowledge of Meaningful Learning Theory by applying it to the topic of analogies (Week 6) and described the importance of ascertaining students' prior knowledge in Week 11. This contrasts with Theo's reflection on his first observation in which he made assumptions about his student's prior knowledge and struggled with helping her as a result.

Over the semester, Theo used his reflections to describe the changes he noticed in the way he conducted his office hours. He acknowledged his unidirectional teaching approach, as well as the efforts he was making to change (Week 5). In the following weeks, he appears to find his "niche" in coordinating students to work together. Like Charlie's use of the word "our", Theo described problem-solving in solidarity with his students (Week

14) and the perceived benefits of doing so, suggesting that his focus shifted from transmission of the correct information to knowledge building. Accordingly, Theo's discourse analysis from Week 14's observation showed a notable increase in the amount of student activity or dialogue, as well as an increase in his dialogic discourse (Figure 2). Like Charlie, he doubled the number of questions he asked in total, and 9/27 of those questions were at the higher level. Further, the monologic discourse he used was largely that of deep knowledge, and the amount of noninteractive time he spent dropped to nearly zero.

Like Charlie, Theo began his first semester by providing some guidance or direction, but did not elaborate on what that meant specifically, and both TIs seemed to imply that part of their role is to hold the correct knowledge and then lead students to the same understanding. Theo's observed teaching went from largely monologic or noninteractive to more student-focused, and Theo's written reflections generally support the claim that he was cognizant of these changes. Like Charlie, as Theo progressed in the semester, his actual practice appears to become more closely aligned to the practices he espouses in his early reflections.

ONE YEAR: NOUREEN AND VIDYA

Like Charlie and Theo, Vidya began her journey as a TI in the Fall of 2017, while Noureen started in Fall 2018. Neither Noureen nor Vidya had taken the Pedagogy Course during the time of this study. For the sake of brevity, the remainder of the TIs' reflection excerpts can be found in the [Supporting Information](#) (Tables S1–S4).

Noureen

In Noureen's first reflection, prior to teaching, she discussed the importance of not "talking at" students, but rather conversing with them (Table S1). However, from first glance, Noureen's initial office hour looked similar to that of Charlie's and Theo's, with nearly one-half coded as monologic discourse and both dialogic discourse and student activity making up less than a quarter each (Figure 5). One difference was that much of her monologic discourse was of the type deep knowledge. That is, Noureen provided reasoning behind the explanations for her student, rather than only bare facts. When writing about her office hour that week, she states that the student was very eager and asked many questions. If Noureen was encouraged by the student's enthusiasm, she may have been more inclined to provide deeper explanations of the content.

Another point of interest is that Noureen asked the most questions (18) of all TIs in their first observation (Table 4). These were nearly all low-level questions (15/18), thus belonging to dialogic shallow knowledge, which was a contrast to the deep knowledge conveyed in her monologic discourse. Upon closer inspection of the transcript, there were multiple instances in which Noureen posed several questions, with one rapidly after the next, despite the fact that the student had not yet answered the first. One possibility is that Noureen interpreted the students' brief silence as confusion and felt her questions were not suitable, and thus she needed to ask another. Another possibility is that her rapid questioning may have been an attempt to keep her student engaged, a goal that she mentioned throughout her reflections (e.g., Semester 1, Week 4). This habit was not something Noureen indicated that she was aware of until her Week 7 reflection. That week, the topic of training was applying the ideas of Meaningful Learning Theory and neuronal networks to reflection. She writes:

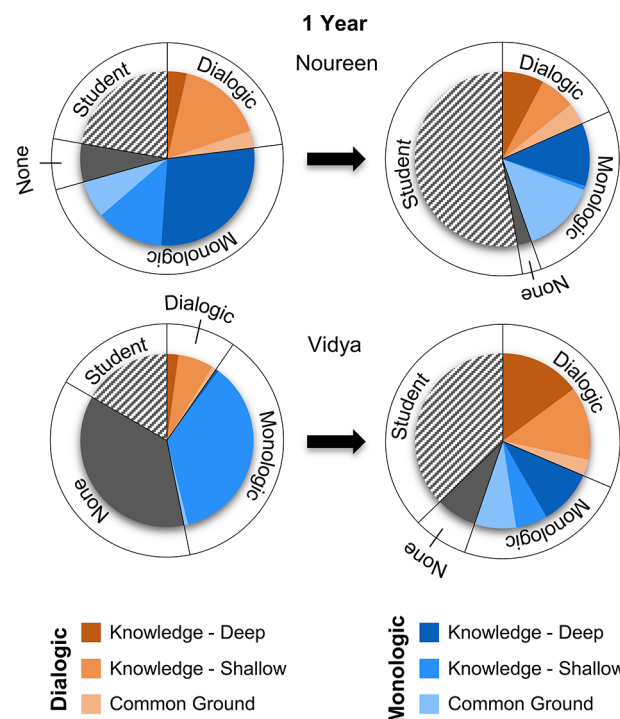


Figure 5. Pie charts illustrate the breakdown of discourse type for Noureen (top) and Vidya (bottom) in their first observations (left) and their second observations conducted 1 year later (right). TI verbal behaviors were classified as "dialogic" or "monologic". Instances in which the students were speaking or working are labeled "Student", while noninteractive time spent is labeled "None".

Table 4. Number of Questions Posed by TIs in Their First and Second Observations

Question Type	Noureen		Vidya	
	1st	2nd	1st	2nd
Low Level	15	10	2	8
High Level	3	11	1	10
Total	18	21	3	18

I learned the significance of letting students "digest" the information they learn and giving them the time to truly understand the material they are being taught. The idea that the smart students are the students that learn fast is simply wrong. (Semester 1, Week 7).

This lesson comes back at the end of the following semester, when Noureen reflects on the changes she had noticed in herself since her first office hour:

Compared to my first learning session, I think I am more confident and comfortable. I try to make my learning sessions more relaxed so students feel comfortable asking questions or getting an answer wrong... I also feel like I have learned to give students more time to answer a question or figure out a solution instead of rushing to help them answer a question. (Semester 2, Week 12).

As mentioned, student engagement was a common theme found throughout Noureen's reflections. This was something she picked up on and practiced while observing the other TIs during Week 4 "roleplay" office hours, and she implemented this strategy in the coming weeks, albeit not without some challenges along the way (e.g., Semester 1, Weeks 6, 8).

Noureen began her second semester in a similar fashion as the first, by emphasizing the importance of being personable with her students and her interest in collaborative learning (Table S2). In her second observation, Noureen demonstrated a notable increase in the amount of time students spent working or talking, representing over half of the total time observed. While the monologic discourse decreased overall, her use of it was primarily to convey deep knowledge or establish common ground. Interestingly, she was the only TI to actually see a decrease in the dialogic discourse; however, this is likely due to the increase in student talking/activity. Moreover, the distribution of her dialogic discourse was more equitable across the types of questions she was asking (10 low-level vs 11 high-level), which was a marked change from her first observation (Table 4). In her reflections, she wrote that she now finds value in letting students take a stronger lead when solving problems, rather than intervening immediately—something she recognized that she used to do (Semester 2, Weeks 10, 11, 14). At the end of her one year, Noureen wrote that she found joy in watching the students find their own success:

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. (Semester 2, Week 15).

Vidya

Similar to Charlie and Theo, Vidya described her overall teaching approach one who guides their students and clarified that it can be in the form of "giving them a simple hint" (Table S3, Week 1). This seems to contrast with her first observation the following week (Figure 5). Looking at the breakdown of her office hour, Vidya actually had the lowest proportion of monologic discourse of all of the TIs observed, with the caveat being that she spent much of her time (over one-third) working independently. Looking at the transcript of her first office hour, the 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. Throughout this, she had only asked a total of three questions (Table 4). In her reflection, Vidya provided more context:

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. (Semester 1, Week 2).

It is worth noting, however, that the observation covered more than just the single challenging problem. Further, the only description of her teaching strategy alluded to using monologic discourse, i.e. "explain the steps to follow".

Throughout the remainder of Vidya's first semester, her reflections discussed the challenges she faced with shifting toward a more student-centered approach, but remained firm in her belief that it is a more effective way to teach (e.g., Semester 1, Weeks 5, 8, 11). For instance, in Week 5, she expressed satisfaction in that her students were able to come up with answers on their own when she offered minimal guidance, but she seemed to lament the fact that she still reverted to monologic discourse for students who lacked the necessary conceptual foundation. Following Week 3's training (Meaningful Learning

Theory), Vidya had written that her main takeaway was "to build on [students'] education and experiences in chemistry and try to find a common ground of communication with the students that will help them understand better". It may be that when Vidya felt the students lacked prior knowledge, she would resort to a more monological approach. As Wells and Arauz³³ 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. In contrast to Vidya's overall satisfaction with her first observation, which was largely noninteractive or monologic, she viewed her own teaching approach in Week 5 with a more critical and discerning lens.

Over the two semesters, Vidya reflected on changes she noticed within herself. Two recurring themes were her increased confidence (e.g., Semester 1, Weeks 13, 14) and that, despite some challenges, she did feel that she improved as a listener (Semester 2, Week 15) and in her ability to get students more engaged in their learning:

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 [is] the best way of learning. (Semester 2, Week 10).

These changes are reflected in the discourse analysis of her second observation (Figure 5). This office hour saw an increase in both the amount of student activity, as well as in her dialogical discourse. Fittingly, there was a marked decline in the amount of noninteractive time. More specifically, she had a greater parity of deep and shallow knowledge for both discourse categories, and the amount of questions she posed to her students jumped from 3 to 18 (Table 4). Part of this transformation may be due to her increase in confidence. With that boost, Vidya may not have felt the need to solve problems on her own before working with the students, as was the case in her first observation. Moreover, that she felt more competent in her abilities to listen, to pose questions to her students, and to facilitate group learning may also be contributing factors. Vidya concluded her TI journey by crediting some of her transformation to the practice office hours:

There was something to learn from every meeting and it all went toward 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 [mistakes] 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. (Semester 2, Week 15).

TWO YEARS: ELEANOR AND NIAN

Eleanor and Nian were both enrolled in the Pedagogy Course at the same time as Theo, in the Fall of 2017, and continued on in the TI program through Spring of 2019. Both had comparable discourse profiles (Figure 6) when they began their tenure as a TI, as well as similar journeys over the years. However, their reflections highlight some key differences (Tables S5–S9).

Eleanor

From the very beginning, Eleanor was cognizant of what she considered to be her weaknesses regarding her abilities to communicate her thoughts on-the-fly and to ask questions rather than explain the content (Table S5, Week 1). She indicated that she had prior experience as a tutor, which may

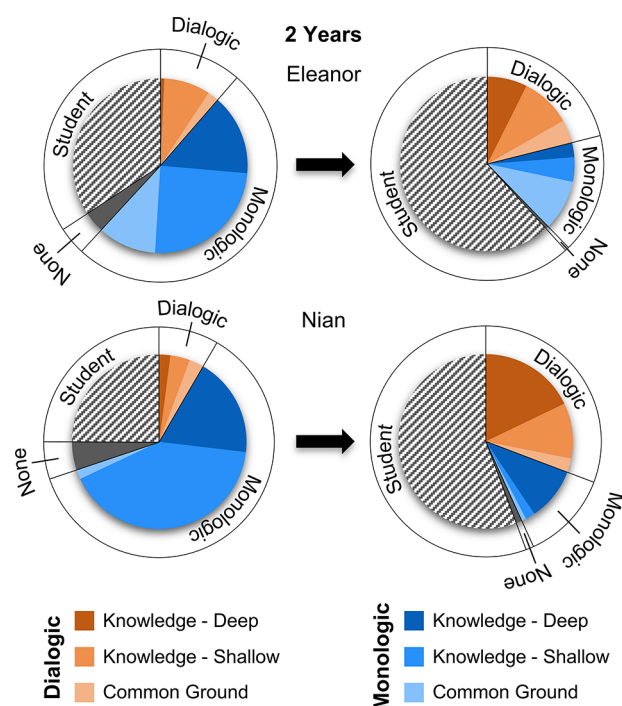


Figure 6. Pie charts illustrate the breakdown of discourse type for Eleanor (top) and Nian (bottom) in their first observations (left) and their second observations conducted 2 years later (right). TI verbal behaviors were classified as “dialogic” or “monologic”. Instances in which the students were speaking or working are labeled “Student”, while noninteractive time spent is labeled “None”.

help to explain her well-articulated sense of her teaching competencies. During the week of her observations, she expressed concerns that she had done too much explaining, which she attributed to the student’s inability to answer the question she posed (Semester 1, Week 2), echoing a challenge Theo also described that week (Figure 3). She concluded with a goal of asking more specific questions in order to mitigate these issues for next time. Despite this assessment, Eleanor’s first observation actually included the most amount of student activity compared to the other TIs’ first observations (Figure 6). Still, half of her observation was monologic in nature, and the dialogic discourse was virtually all shallow knowledge. Accordingly, all nine of the questions she posed were low-level questions (Table 5).

Table 5. Number of Questions Posed by TIs in Their First and Second Observations

Question Type	Eleanor		Nian	
	1st	2nd	1st	2nd
Low Level	9	6	5	9
High Level	0	8	1	14
Total	9	14	6	23

Throughout Eleanor’s first semester, she invoked the ideas of dialogic and monologic (referred to in the Pedagogy Course as “univocal”⁴⁴) discourse frequently in relation to her teaching. For example, she described a successful learning session as “...one in which the TI and students are carrying out dialogic discourse... the TI should not be lecturing, unless the student demonstrates no basic understanding of the concept” (Semester 1, Week 11). Like Vidya and Noureen, Eleanor believed that the

type of discourse a TI uses should be dependent on the context and student and appeared to use this as a standard for evaluating her learning session each week: for example, in Week 8, she expressed dissatisfaction with her perceived overuse of monologic discourse. However, by the end of the semester, she felt as though this was where she achieved her greatest improvement: “The biggest change I’ve noticed about my teaching is, ironically, that I do not teach as much as I used to... I tend to ask more questions to students in a way that pushes them to learn concepts on their own.” (Semester 1, Week 14). Perhaps relatedly, Eleanor also felt that she improved in her ability to verbalize her thoughts (Semester 1, Week 1 vs Week 14).

In her last semester as a TI, Eleanor’s goals for teaching now centered around accessing students’ prior knowledge via questioning, writing that “effective teaching requires understanding your student’s knowledge level. Your teaching approach will vary for different types of students, and this is why it’s so important to first gauge student understanding” (Semester 4, Week 1). She identified her weakness in this area in Week 5, as she wrote that she tended to stay at the “lower levels of Bloom’s Taxonomy”, a reference to the training from two weeks prior. Further, there were multiple weeks in which Eleanor cited her other perceived weakness, eliciting student engagement (Semester 4, Weeks 10, 15). However, her second observation showed that her overall discourse profile looked quite different from her first observation in nearly every regard (Figure 6). This observation was the most student-centered of all observations conducted, and her office hour went from just about half monologic to less than one-fifth. As such, it was curious that she felt she was still struggling with the amount of “lecturing” she did. It could be speculated that Eleanor’s lack of confidence led to a discrepancy between her perception and her actual practice; however, a further look into her final reflection appears to dispute this:

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 is okay to make mistakes in front of students and to remain confident in my learning sessions. (Semester 4, Week 15).

Alternatively, it may be 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. Like Vidya, Eleanor viewed her learning sessions with a discerning lens, which was reflected in her writing. Given that she began the Pedagogy Course with a well-formed sense of her abilities and weaknesses, which she revisited in subsequent reflections, it is possible that her tendency toward self-critiques is simply part of her nature.

Nian

Nian’s first observation did not stand out in any notable way compared to the other TIs: predominantly monologic, with emphasis on shallow knowledge (Figure 6), and he posed six questions total, of which five were low-level (Table 5). In his first reflection, prior to his observation, he wrote that he enjoys “teaching and explaining so others learn and do not simply get questions right” (Table S7, Week 1). However, he went on to say that this task requires him to “think from different perspectives as well”. While his satisfaction from explaining may have accounted for the monologic discourse that dominated his first observation (Figure 6), he seemingly acknowledged student

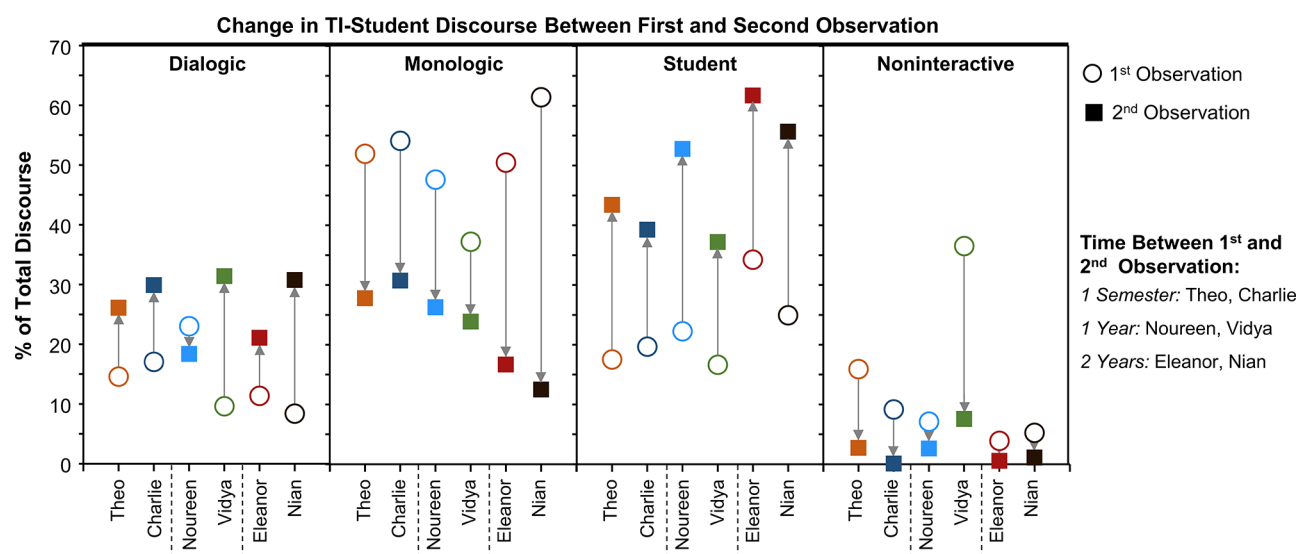


Figure 7. A summary of the changes in discourse between TIs and General Chemistry students, classified as dialogic, monologic, student dialogue/activity, or noninteractive. Open circles correspond to the percentage of total discourse (by amount of time) that was coded in the first observation, whereas the solid-colored squares represent the percentage of total discourse from the second observation.

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. Further, while his postobservation reflection suggested that he was satisfied with the fact that he was “able to provide a lot of tips on how I used to solve the problems” (Semester 1, Week 2), he did not indicate that he found his methods to necessarily be better.

Nian’s aim to be open-minded remained a common theme throughout his first semester of reflection, writing that he enjoyed helping “different types of students” and, following his observation of another TI, stated that he liked the idea of encouraging his students to approach questions from multiple perspectives and sharing their strategies among each other (Semester 1, Weeks 4, 8). Perhaps accordingly, he later described a successful office hour as one which utilizes more collaborative learning:

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. (Semester 1, Week 11).

At the conclusion of his first semester, he attributed his shift toward more student engagement to his teaching experiences, stating that he adapted his preparation each week based on the previous weeks, as well as to the content stressed in the Pedagogy Course (Semester 1, Week 14).

These themes carried over throughout Nian’s time as a TI, into his fourth semester, where he expressed confidence in his command of the content and reinforced his belief that “thorough understanding” means thinking about the content in “many different dimensions” (Semester 4, Week 1). By this time, Nian’s reflections indicate that he had included more collaborative learning in his teaching, utilizing group work and the white board space in his office hours (e.g., Semester 4, Weeks 3, 5). These patterns were reflected in his second observation, in which the majority of his time recorded was consumed by student dialogue/activity, while the rest was largely dialogic in nature. Reflected in this breakdown is the fact that Nian asked 23 questions, of which 14 were high-level (Table 5). This was in

spite of the fact that, in Nian’s view, the students did not have a strong foundation for the content that he perceived to be challenging. Of note, however, he also wrote that “we were able to work through it”, a sentiment of solidarity previously shared by Noureen and Charlie (Semester 4, Week 15). While Nian had endorsed many of these principles in his first semester, he was not necessarily able to implement them. However, by his fourth semester, Nian’s espoused theories were more aligned with his practical theories.

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 7 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/activity, with decreases in monologic discourse and non-interactive time. For all of the TIs, monologic discourse comprised the largest percentage of the total time in their first observation. Further, with the exception of Eleanor and Nian, each TI’s percentage of dialogic discourse was comparable to

their respective percentage of student dialogue/activity in the first observation. Monologic discourse and student dialogue/activity generally saw the largest shifts across all of the TIs.

Type and Depth of Discourse

Figure 8 provides additional data as to how the second and third dimensions of discourse, type and depth of information,

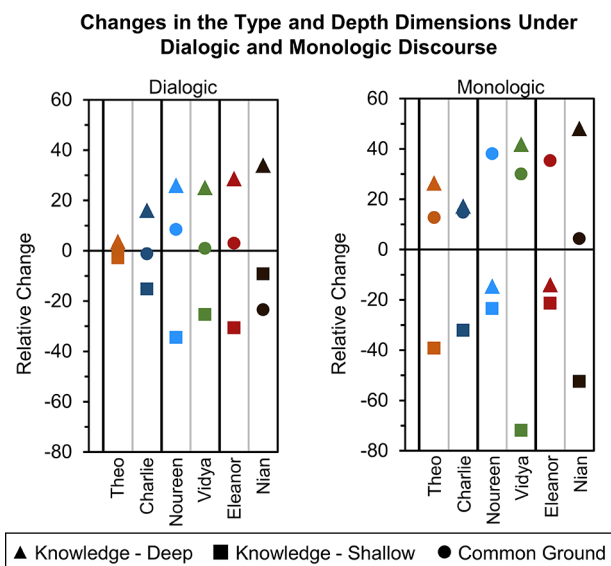


Figure 8. A summary of the changes in the type of information communicated by the TIs for both dialogic (left) and monologic (right) discourse. The amount in each of the three categories was calculated as a percentage of the total dialogic or monologic discourse. The graphed data here represents the difference in percent makeup between the first and second observation. For example, “Knowledge-Deep” constituted 30.1% of Nian’s Monologic Discourse in his first observation and 78.2% in his second observation, for an increase of 48.1 (as shown on the graph).

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 percentages of deep knowledge, shallow knowledge, and common ground were determined for both dialogic and monologic discourse (e.g., “What percentage of the dialogic discourse was labeled “common ground”?”). 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. For example, Nian overall declined in the amount of time spent engaged in monologic deep knowledge (from 18.5% to 9.8%, Table S11) between his first and second observation. However, deep knowledge represents a larger percentage of his monologic discourse in his second observation compared to his first (from 30.1% to 78.4%, Table S12). 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 all TIs, their monologic discourse incorporated more common ground in their second observation, and for most TIs, this was accompanied by increases in deep knowledge, save for Noureen and Eleanor. In fact, Noureen and Eleanor exhibited remarkably similar profiles in both the dialogic and monologic categories. With that, there were no clear trends 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 8. The full extent of the raw data can be found in Tables S11–S13 of the Supporting Information.

CONCLUSIONS

The discourse analysis of observational data in this paper provides 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 CCE- and non-CCE TIs explicitly cite the topics and skills that they gained through their respective formal training, indicating that they are essential components of the CCE and TI programs. The six TIs in this multicase study began their role as a TI with similar beliefs and dialogue patterns. Possibly stemming from 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, initially 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 initially used a nontrivial portion of their office hour to solve problems independently before engaging with their students, likely due to a lack of confidence or deficiency in their content knowledge.

The first research question (RQ1) explored the extent to which students change in their use of monologic vs dialogic discourse. The results presented here show that 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 2-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.

RQ2 dove deeper into the specific content of the dialogue and looked at how it changes over time. In general, the TIs 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.

RQ3 probed the alignment between students teaching beliefs and their teaching behaviors. To answer this, 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.

Considering the theory–practice paradigm, the results from this study suggest a gap exists between the TIs' practical theories and espoused theories when they begin the TI program. Despite endorsing sound theories about learning, the TIs appear to 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.³⁸ Similarly, in a recent case study examining preservice science teachers, it was found that when the participants did not feel in command of the content or lacked confidence, they resorted to procedural teaching, rather than the more student-centered practices that they had previously demonstrated with other content.⁴⁵ This phenomenon has been observed in graduate teaching assistants as well, namely that when the TAs felt unprepared to teach their inquiry-based teaching laboratories, they resorted to more instructor-centered teaching.⁴⁶ 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 and content knowledge (Vidya). Over time however, this theory–practice gap appears to narrow in the TIs. Interestingly, while their 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. The literature overwhelmingly supports the notion that one's prior teaching experience further shapes their current pedagogical knowledge and practice,⁴⁷ and this is also made clear in the TIs' reflections. However, as presented above, at least some of the changes the TIs discussed were attributed to their concurrent training, suggesting there is 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, it became apparent that 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 unclear or added to the student's confusion or anxiety. It is also plausible that there is an element of discomfort during awkward silences, which some TIs may instinctively react to by giving the answers instead. 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 a humorous exercise

initially, but affording them the opportunity to sit in silence for several seconds after asking a question might help 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. Despite the fact that this practice was covered in the TIs' training, it was still something that several of them reported as a challenge. This exercise is likely to be highly topic-specific, so this would be a practice worth visiting multiple times and applied to the different topics that the TIs teach. It may also be useful for the TIs to explore effective questioning with different types of content, e.g., conceptual, algorithmic, graphical, etc. Bloom's taxonomy may be a helpful place to start, so that students can understand what is meant by "higher level questions".^{48,49} 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 judgments about an answer are most productive once students have demonstrated a foundation of knowledge in order to build a deeper understanding.

All of the TIs in this study reflected on the lessons learned from either the "roleplaying" office hours activity and/or the assignment in the Pedagogy Course in which they needed to observe another TI. This activity gave new TIs an opportunity to see how the more experienced TIs handled different situations, as well as a chance to practice their strategies in a lower-stakes setting. Given that teaching experience is vital for informing one's teaching practices,⁴⁷ it is not surprising that an activity such as this has been shown to be beneficial for peer tutors who may be lacking in their confidence.⁵⁰ Likewise, as their colleagues play the role of a student, they can mimic the behaviors and questions that they have experienced to perhaps give the new TIs a fuller picture of what to expect. In the TI program for this study, each training session had approximately 12–16 TIs. It was found that separating them into 2–3 groups for the roleplaying was more feasible and alleviated the pressure felt by one TI being the solo center of attention.

Finally, periodic reminders during training sessions should prompt peer instructors to consider what actions they are taking at the cost of their students' involvement. For example, peer instructors should be encouraged to establish a general habit of not picking up the pencil/chalk to write or the calculator to perform math, and instead hand the tools off to students. One training activity could involve discussing or roleplaying scenarios in which the peer instructors decide when this "rule" is or is not the most productive to the students' learning. Likewise, this is a habit that the pedagogy instructor can model and reinforce throughout the course.

■ LIMITATIONS AND FUTURE DIRECTIONS

This study utilized two different forms of qualitative data collection to perform a multicase 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 not only would be useful to further engage with the TIs about their beliefs and perceptions of their learning sessions, but also would 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.

■ ASSOCIATED CONTENT

SI Supporting Information

The Supporting Information is available at <https://pubs.acs.org/doi/10.1021/acs.jchemed.2c00170>.

Sample reflection prompt, full list of question types and codes with examples, as well as additional raw data from the discourse analysis of the observations (PDF)

■ AUTHOR INFORMATION

Corresponding Authors

Emily L. Atieh – Department of Chemistry, University of Virginia, Charlottesville, Virginia 22904-1002, United States; orcid.org/0000-0002-7143-1209; Email: emily.atieh@virginia.edu

Darrin M. York – Department of Chemistry and Chemical Biology and Cyberlearning Innovation and Research Center, Rutgers, The State University of New Jersey, Piscataway, New Jersey 08854-8087, United States; orcid.org/0000-0002-9193-7055; Email: darrin.york@rutgers.edu

Complete contact information is available at: <https://pubs.acs.org/10.1021/acs.jchemed.2c00170>

Notes

The authors declare no competing financial interest. This manuscript is reprinted in part with permission from Atieh, E. L. Characterizing the Progression of Knowledge, Beliefs, and Behaviors in Peer Instructors: An Evaluation of the General Chemistry Teaching Interns. Ph.D. Dissertation, Rutgers University, New Brunswick, NJ, 2020. Copyright (2020) Emily Lauren Atieh.

■ ACKNOWLEDGMENTS

We would like to express our sincerest gratitude for the advice of Dr. Mary Emenike and Dr. Marc Muñiz, as well as the cooperation and support of the Rutgers Department of Chemistry and Chemical Biology. We would also like to thank the Teaching Interns for their participation in this project and for their valuable feedback in helping to shape the TI and CCE program. This work would not have been possible without the support of the Cyberlearning Innovation and Research Center (CIRC), funded through the School of Arts and Sciences at Rutgers, New Brunswick. Lastly, we are grateful for the funding provided by the National Institutes of Health [GM62248].

■ REFERENCES

- (1) 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.
- (2) Lewis, S. E. Retention and reform: An evaluation of peer-led team learning. *J. Chem. Educ.* **2011**, *88* (6), 703–707.
- (3) 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.
- (4) 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.
- (5) 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.
- (6) 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.
- (7) Amaral, K. E.; Vala, M. What teaching teaches: Mentoring and the performance gains of mentors. *J. Chem. Educ.* **2009**, *86* (5), 630.
- (8) 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.
- (9) 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.
- (10) Atieh, E. L.; York, D. M. The Teaching Internship in General Chemistry. <https://www.elearning.rutgers.edu/chem-ti-program> (accessed on November 11, 2019).
- (11) 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.
- (12) 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.
- (13) 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.
- (14) 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.
- (15) Murphey, T. Near peer role models. *Teachers Talking to Teachers: JALT Teacher Education SIG Newsletter* **1996**, *4* (3), 21–22.
- (16) Martin, D. C. *The Learning Center: A Comprehensive Model for Colleges and Universities*; Aquinas College: Grand Rapids, MI, 1977.
- (17) 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.
- (18) 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.
- (19) 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*; ACM, 2011; pp 201–206.
- (20) Wallace, R. A. An alternative to assembly-line education: undergraduate teaching assistants. *Teach. Sociol.* **1974**, *2*, 3–14.
- (21) 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.
- (22) Gosser, D. K.; Roth, V. The workshop chemistry project: Peer-led team-learning. *J. Chem. Educ.* **1998**, *75* (2), 185.
- (23) 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.
- (24) 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.
- (25) 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.

- (26) Solomon, J. Social Influences on the Construction of Pupils' Understanding of Science. *Studies in Science Education* **1987**, *14* (1), 63–82.
- (27) Bodner, G. M. Constructivism: A theory of knowledge. *J. Chem. Educ.* **1986**, *63* (10), 873.
- (28) Vygotsky, L. S. *Mind in Society: The Development of Higher Psychological Processes*; Harvard University Press: Cambridge, MA, 1978.
- (29) Otero, V.; Pollock, S.; McCray, R.; Finkelstein, N. Who is responsible for preparing science teachers? *Science* **2006**, *313* (5786), 445–446.
- (30) 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.
- (31) 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.
- (32) Dohrn, S. W.; Dohn, N. B. The role of teacher questions in the chemistry classroom. *Chem. Educ. Res. Pract.* **2018**, *19* (1), 352–363.
- (33) Wells, G.; Arauz, R. M. Dialogue in the Classroom. *Journal of the Learning Sciences* **2006**, *15* (3), 379–428.
- (34) 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.
- (35) O'Connor, C.; Michaels, S. When is dialogue 'dialogic'? *Hum. Dev.* **2007**, *50* (5), 275–285.
- (36) Murphey, T.; Arao, H. Reported belief changes through near peer role modeling. *TESL-EJ* **2001**, *5* (3), 1–15.
- (37) Graesser, A. C.; Person, N. K. Question Asking During Tutoring. *Am. Educ. Res. J.* **1994**, *31* (1), 104–137.
- (38) Buitink, J. What and how do student teachers learn during school-based teacher education. *Teaching Teach. Educ.* **2009**, *25* (1), 118–127.
- (39) Argyris, C.; Schön, D. A. *Theory in Practice: Increasing Professional Effectiveness*, 1st ed; Jossey-Bass Publishers: San Francisco, 1974.
- (40) 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.
- (41) Ausubel, D. P. *The Psychology of Meaningful Verbal Learning*; Grune & Stratton: New York, NY, 1963.
- (42) Zull, J. E. *The Art of Changing the Brain: Enriching the Practice of Teaching by Exploring the Biology of Learning*, 1st ed.; Stylus Publishing: Sterling, VA, 2002; p 263.
- (43) Atieh, E. L.; York, D. M. The Certificate in Chemistry Education. <https://www.elearning.rutgers.edu/chem-ccc> (accessed on November 11, 2019).
- (44) Knuth, E.; Peressini, D. Unpacking the nature of discourse in mathematics classrooms. *Mathematics Teaching in the Middle School* **2001**, *6* (5), 320–325.
- (45) Coetzee, C.; Rollnick, M.; Gaigher, E. Teaching Electromagnetism for the First Time: a Case Study of Pre-service Science Teachers' Enacted Pedagogical Content Knowledge. *Res. Sci. Educ.* **2020**, *52*, 357–378.
- (46) Kurdziel, J. P.; Turner, J. A.; Luft, J. A.; Roehrig, G. H. Graduate Teaching Assistants and Inquiry-Based Instruction: Implications for Graduate Teaching Assistant Training. *J. Chem. Educ.* **2003**, *80* (10), 1206.
- (47) Carlson, J.; Daehler, K. R.; Alonzo, A. C.; Barendsen, E.; Berry, A.; Borowski, A.; Carpendale, J.; Kam Ho Chan, K.; Cooper, R.; Friedrichsen, P.; Gess-Newsome, J.; Henze-Rietveld, I.; Hume, A.; Kirschner, S.; Liepertz, S.; Loughran, J.; Mavhunga, E.; Neumann, K.; Nilsson, P.; Park, S.; Rollnick, M.; Sickel, A.; Schneider, R. M.; Suh, J. K.; van Driel, J.; Wilson, C. D. The Refined Consensus Model of Pedagogical Content Knowledge in Science Education. In *Repositioning Pedagogical Content Knowledge in Teachers' Knowledge for Teaching Science*; Hume, A., Cooper, R., Borowski, A., Eds.; Springer Singapore: Singapore, 2019; pp 77–94.
- (48) 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.
- (49) Krathwohl, D. R. A revision of Bloom's taxonomy: An overview. *Theor. Pract.* **2002**, *41* (4), 212–218.
- (50) Lin Siew, F.; Lin Chee, Y. Learning through teaching: tutors' reflections and recommendations when facilitating student learning in case studies through peer tutoring. *J. Emerging Trends Educ. Res. Policy Stud.* **2016**, *7* (4), 276–282.

Recommended by ACS

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

Emily L. Atieh and Darrin M. York

JULY 28, 2020
JOURNAL OF CHEMICAL EDUCATION

READ 

Evaluating the Experiences of Different Identity Groups in a General Chemistry Course

Oluwatobi Odeleye, Diya Tang, et al.

NOVEMBER 08, 2022
JOURNAL OF CHEMICAL EDUCATION

READ 

Using Structured Teams to Develop Social Presence in Asynchronous Chemistry Courses

Charity Flener-Lovitt, Rui Han, et al.

AUGUST 18, 2020
JOURNAL OF CHEMICAL EDUCATION

READ 

Collaborative Middle School Science Outreach Project Using the Japanese Lesson Study Model

Chris L. Craney, Jessica Kissel, et al.

APRIL 09, 2020
JOURNAL OF CHEMICAL EDUCATION

READ 

Get More Suggestions >