Chemistry Education Research and Practice

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Journal:	*Chemistry Education Research and Practice*
Manuscript ID	RP-ART-03-2024-000093.R2
Article Type:	Paper
Date Submitted by the Author:	14-Jul-2024
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Received 00th January 20xx,
Accepted 00th January 20xx
DOI: 10.1039/x0xx00000x

A Case Study on Graduate Teaching Assistants' Teacher Noticing When Enacting a Case-Comparison Activity in Organic Chemistry

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Graduate teaching assistants (GTAs) hold a unique positionality as instructors and research mentors to undergraduate students, research mentees to faculty members, and employees to the institution. With limited pedagogical training and teaching resources, the enactment of planned teaching activities and learning resources may be influenced by how GTAs conceptualize their teacher identity, role, and experiences. In this study, we explored how chemistry GTAs enacted a scaffolded, cooperative-learning case-comparison activity in a second-semester organic chemistry laboratory course. Our study was guided by the conceptual framework of teacher noticing. Teacher noticing – an instructor observing "important" instructional moments and connecting their observations to theory and practice – is a part of developing instructional responses based on students' reasoning. Pairing this conceptual framework with a case study methodology, we recruited two GTAs, and conducted a pre-observation interview, two observations, and a post-observation interview. We explored GTAs' teacher noticing – what they observed and interpreted as well as how they shaped and responded. We exposed the tension and the resolution between learning objectives (*i.e.,* objectives set by the instructional team for students) and teaching objectives (*i.e.,* objectives set by the GTAs for themselves and their students). GTAs' framing seemed to influence their shaping, and their shaping seemed to balance the instructional team's learning objective and GTAs' teaching objectives. Because chemistry GTAs serve as instructors in many science undergraduate courses, understanding the unique GTA framing may support both graduate and undergraduate learning experiences. Furthermore, our study has implications for researchers who design organic chemistry learning resources to consider different ways GTAs may support students' learning. This study additionally has implications for faculty instructors to develop transformative, consistent professional development opportunities focused on transparency, collaboration, and community in teacher learning.

Introduction

Recent calls for more transformative and engaging activities in post-secondary chemistry classes have led to the intentional development and research of reformed materials (Cooper *et al.*, 2019; Talanquer and Pollard, 2017). However, few studies have focused on how faculty instructors or graduate teaching assistants (GTAs) influence the enactment of these materials in the classroom or their role in supporting students' reasoning and problem-solving skills in chemistry (Andrews *et al.*, 2019; Apkarian *et al.*, 2021; Auerbach and Andrews, 2018). This study explored how chemistry GTAs enacted a scaffolded, cooperative-learning case-comparison activity in a second-semester organic chemistry laboratory. Scaffolding is a part of both instructional design and instructional practice.

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Electronic Supplementary Information (ESI) available: [details of any supplementary information available should be included here]. See DOI: 10.1039/x0xx00000x

Scaffolding as Instructional Design

Wood, Bruner, and Ross (1976) introduced the idea of scaffolding – breaking down a challenging conceptual task into elements that are within the learner's zone of proximal development (Wertsch, 1991) while building up to the completion of more complex tasks. Scaffolding is used as a temporary support structure (*e.g.*, sentence starters, guiding questions, prompts) to aid students in the development of problem-solving skills that might not be independently developed (Kang *et al.*, 2014). The temporary support is meant to allow students to "cognitively engage with the full process or activity" while developing more complex problem-solving skills (Calder, 2015, p. 1121). In organic chemistry instruction and education research, one of these skills is multivariate reasoning.

Multivariate reasoning is defined as using or considering multiple variables to construct explanations about chemical phenomena and is important for organic chemistry students to develop when reasoning through reaction mechanisms with multiple implicit properties (Caspari and Graulich, 2019). However, Sevian and Talanquer (2014) identified and implicated that organic chemistry students may need additional tangible support to engage in higher-order reasoning, such as multivariate reasoning (Caspari and Graulich, 2019). Case-comparison tasks have elicited students' multivariate reasoning (Caspari and Graulich, 2019; Zaimi *et al., submitted*), and these studies recommended scaffolded case-comparison activities. Case-comparison activities have been studied in both research settings (Caspari and Graulich, 2019; Kranz *et al.*, 2023) and classroom settings as think-pair-share activities (Watts *et al.*, 2021) and cooperative-learning activities (Haas *et al.*, 2024). Furthermore, Haas *et al.* (2024) have recommended scaffolded, cooperative-learning case-comparison activities. However, current classroom-setting studies have focused on what reasoning is elicited by the activity from the students (*via* written artifacts and interviews) (Haas *et al.*, 2024; Watts *et al.*, 2021) rather than how instructors facilitate the enactment of these activities and influence the student learning outcomes (*via* interviews and observations). Thus, building on this literature, the activity enacted in this study is a scaffolded, cooperative-learning case comparison.

Scaffolding as Instructional Practice

This study centred how GTAs enacted a scaffolded, cooperative-learning case-comparison activity. Scaffolding was a part of instructional design, but, because faculty instructors design and GTAs enact, scaffolding was also used as an instructional practice. Scaffolding as an instructional practice is part of taking an inquiry stance as "question-driven learning" (Kawalkar and Vijapurkar, 2013). Therefore, scaffolding as an instructional strategy or practice often looks like asking students questions, starting with lower-level questions and building up to more complex questions (Kawalkar and Vijapurkar, 2013; Koufetta-Menicou and Scaife, 2000). Moving toward more transformative learning environments, "the objective [of question asking] in the inquiry classroom is to move away from this simple recollection of the 'right answer' and towards coherent explanations of the phenomena in context" (Kawalkar and Vijapurkar, 2013, p. 2006). These scaffolded questions that instructors ask are important to creating a learning environment that supports students' sensemaking (Benedict-Chambers *et al.*, 2017), indicating that the quality and context of question-asking are important to *good teaching* (Roth, 1996). Good teaching in post-secondary chemistry courses requires supporting the enactment of instructional practices, like scaffolding, and incentivising the design of reformed instructional activities, broadly like active-learning activities and specifically like scaffolded, cooperative-learning activities. Thus, while the activity in this study was designed and implemented to align with and build upon the literature, the novel goal of this study was the enactment of this reformed learning activity.

Chemistry Graduate Teaching Assistants Enacting Active-Learning Activities

Recent calls for reformed activities have recommended active-learning activities, which can range in time commitments (*i.e.,* instructor preparation and class time), class sizes, materials and resources, and structures (*i.e.,* small-group work, whole-group discussions, and peer-to-peer or instructor-student interactions) (McConnell *et al.*, 2017). However, implementation does not necessarily guarantee enactment as designed and envisioned by education researchers, instructional designers, or faculty instructors (Spencer, 2022; Spencer and Shultz, *submitted;* Stains and Vickrey, 2017). Considering research-intensive (R1) universities, this enactment often falls on GTAs in their discussion and laboratory sections. Despite their part in the design and implementation process, GTAs' enactment in their sections and, thus, their transformation of these reformed activities remains understudied.

Graduate students are researchers and students as well as GTAs. Chemistry GTAs teach laboratory and discussion sections, where they provide 15-30 undergraduate students one-on-one contact, oftentimes more facetime than large-enrolment faculty instructors (Geragosian *et al.*, 2024; Zotos, 2022; Zotos *et al.*, 2021). GTAs are indispensable, influential teachers, but studies reported that they have minimal teaching experiences and that departments provide them minimal teacher training and professional development opportunities. Because of this, studies reported that chemistry GTAs are confused about their roles (Duffy and Cooper, 2020) and are frustrated in their roles (Zotos *et al.*, 2020). Specifically, Zotos *et al.* (2020) found that chemistry GTAs feel unprepared and exhausted and view themselves not as teachers but as managers.

In the absence of substantial teacher training, GTAs' learning experiences frame their teaching. However, these learning experiences have historically been traditional classrooms, not reformed classrooms (Luft *et al.*, 2004). For example, in chemistry, reformed classrooms have typically been inquiry-based laboratories (*e.g.,* cooperative-learning or project-based-learning laboratories). Studies demonstrated that inquiry-based laboratory GTAs know their roles, but they also exposed a tension between what GTAs know what to do (*e.g.,* guide students' reasoning) and what they want to do (*e.g.,* sometimes explain chemistry content) (Duffy and Cooper, 2020; Sandi-Urena *et al.*, 2011; Sandi-Urena and Gatlin, 2013; Wheeler *et al.*, 2019). Regarding the root of this tension, Duffy and Cooper (2020) proposed a lack of confidence in students' knowledge and skills, and Wheeler *et al.* (2019) proposed a lack of confidence and skill in GTAs' facilitation. However, a few chemistry GTAs did feel confident in their facilitation, and these GTAs cited their previous learning experiences (Wheeler *et al.*, 2019), previous teaching experiences (Maxwell *et al.*, 2023), or supportive staff meetings (Maxwell *et al.*, 2023). An inquiry stance (*i.e.,* guiding students' reasoning) requires a strong knowledge for teaching (Bond-Robinson, 2005), which is multifaceted and is limited by a lack of resources, time, and professional development as well as the learning environment itself (Sandi-Urena and Gatlin, 2013). Thus, GTAs' teaching experiences also frame their teaching. While Zotos *et al.* (2020) and Sandi-Urena *et al.* (2011) found that chemistry GTAs viewed themselves as managers, Sandi-Urena and Gatlin (2013) found that this view shifted from managers to mentors and continued to shift as GTAs continued to teach inquiry-based labs.

In addition to how GTAs view themselves, Zotos *et al.* (2020) explored how GTAs set objectives and found that GTAs set teaching objectives (*i.e*., objectives set by the GTAs for themselves and their students) instead of learning objectives (*i.e.,* objectives set by the instructional team for students). Ideally, learning objectives should frame lesson plans and assessments (Harshman and Yezierski, 2015). However, GTAs do not have this curricular power, leading to the existence of GTAs' teaching objectives that may or may not align with faculty instructors' learning objectives (Zotos *et al.*, 2020). Thus, this study explored how GTAs enacted a scaffolded, cooperative-learning case-comparison activity and what enactment meant for instructors who have limited curricular power.

Conceptual Framework of Teacher Noticing

In order to explore graduate teaching assistants' (GTAs') enactment of a scaffolded, cooperative-learning activity, we operationalized teacher noticing. Traditionally and primarily explored in mathematics education literature, teacher noticing has captured the discipline-specific teacher noticing of K-12 mathematics teachers (Goodwin, 1994; Jacobs *et al.*, 2010). Recently in the chemistry education literature, teacher noticing has captured the discipline-specific teacher noticing of chemistry GTAs (Geragosian *et al.*, 2024). As a professional skill, teacher noticing develops teaching, as a reflective framework for what teachers notice (or do not notice) (Gibson and Ross, 2016; Jacobs *et al.*, 2010). However, van Es and Sherin (2021), Sherin and van Es (2009), and Jacobs *et al.* (2010) suggested that professional development and teaching experience develop teacher noticing. Therefore, teacher noticing is a dynamic process, reciprocally informing teaching while being informed by teaching (Luna, 2018). Teachers, with varying levels of experience, pedagogical training, professional development, and sophistication of content or pedagogical knowledge, tacitly, implicitly, and explicitly notice. While studies have explored instructors' teacher noticing (Jacobs *et al.*, 2010; Louie *et al.*, 2021; van Es and Sherin, 2021), only one study has explored *chemistry* GTAs' teacher noticing (Geragosian *et al.*, 2024). Our study explored chemistry GTAs' teacher noticing, as GTAs' teacher noticing could differ from instructors' teacher noticing due to the amount of professional development and teaching experience as well as GTAs' unique positionality.

Attending, Interpreting, and Responding

Originally, teacher noticing has been conceptualized as how teachers actively and selectively *attend to* instructional moments (*i.e., attending*), how they *interpret* those instructional moments (*i.e. interpreting*), and how they *respond to* those instructional moments (*i.e., responding)*. Thus, teacher noticing has been operationalized as the Attending, Interpreting, Responding (AIR) codes (Louie *et al.*, 2021). Commonly, these AIR codes have been presented with arrows starting at attending, continuing to interpreting, and ending at responding, conceptualizing a cyclical pattern of teacher noticing (Figure 1).

GTAs are presented with a "blooming, buzzing confusion of sensory data" of instructional moments in the classroom (Sherin *et al.*, 2011, p. 5). First, a GTA *attends to* or observes an instructional moment (*i.e., attending*) (*e.g,* student talk, student work, student resources, group placement, student answers, student questions, or students themselves). Attending is active and selective with an "awareness of awareness" (Mason, 2011, 2009). Thus, the GTA can actively, selectively choose not to attend to an instructional moment based on "worthiness" (Sherin and Star, 2011). Next, the GTA *interprets* the instructional moment (*i.e., interpreting*) (*e.g.,* student progression, student engagement, and student understanding), pulling out their pedagogical reasoning and drawing from their content knowledge, pedagogical knowledge, and instructional experiences (van Es and Sherin, 2021). Then, the GTA *responds to* an instructional moment (*i.e., responding*) (*e.g.,* teaching practice, classroom management, time management, or instructional resources) (Jacobs *et al.*, 2010). Responding can be planned, impromptu, tacit, or proposed. Similar to attending, responding is active and selective. Thus, the GTA can actively, selectively choose not to respond to an instructional moment based on interpretations. GTAs return to the "blooming, buzzing confusion" of instructional moments (Sherin *et al.*, 2011, p. 5) and repeat the cycle (Sherin and Star, 2011) (Figure 1).

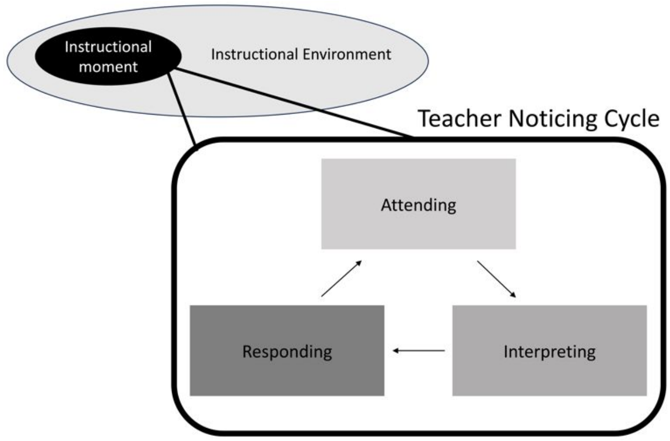

Figure 1 A Cycle of Teacher Noticing Using the Attending, Interpreting, and Responding (AIR) Aspects This figure has been adapted from Geragosian et al. (2024).

Shaping and Framing

Recently, teacher noticing has been conceptualized as how teachers shape (*i.e., shaping)* and frame (*i.e., framing*) instructional moments, in addition to the original AIR aspects. Capturing and operationalizing all five aspects depends on the method of collecting teacher noticing data. Teacher noticing has been captured *via* video clubs with think-aloud or written responses, written scenarios with written responses, or classroom observations and interviews with clips of classroom events from those observations (Sherin *et al.*, 2011). The methods have successfully captured the AIR aspects. Our study design paired audiovisually recorded classroom observations and semi-structured interviews with clips of the classroom events from the classroom observations for the participants to verbally reflect on. The audiovisual observations captured in-depth reflection and analysis on attending and responding; moreover, the semi-structured interviews captured in-depth reflection and analysis on interpreting and how interpreting influenced responding (and vice versa). We captured and operationalized the AIR codes, but, beyond the AIR codes, we noted moments where our participants bounced between interpreting and responding (*i.e., shaping)* or contextualized the AIR codes (*i.e., framing)*. Therefore, we captured and operationalized the *shaping* and *framing* codes, in addition to the AIR codes (Figure 2).

Shaping is active and selective, where the GTA creates instructional moments (*e.g.,* asking a series of probing questions) in order to elicit students' reasoning and "gain access to additional information that supports their noticing" (van Es and Sherin, 2021, p. 19). In contrast to responding, van Es and Sherin (2021) posited that "'shaping' involves teachers and students engaging in an interaction with each other, in the moment" (van Es and Sherin, 2021, p. 24). Prominently, shaping involves the GTA asking students questions, and Smith and Sherin (2019) denoted that some questions are shaping (*e.g.,* assessing questions that reveal students' thinking) but that other questions are not (*e.g.,* advancing questions that further students' thinking). While mathematics education researchers have bound shaping, we expand these boundaries to acknowledge how advancing questions might be GTAs' attempts at shaping.

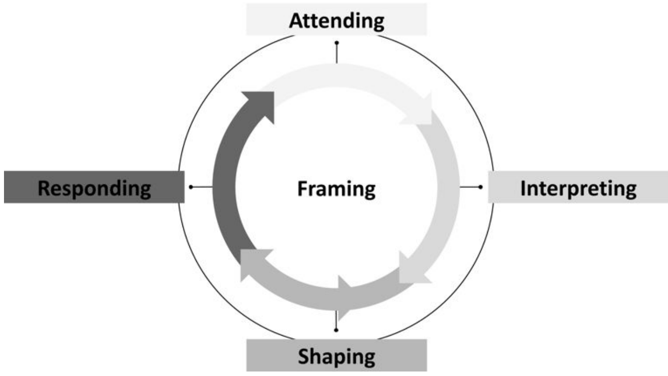

Figure 2 Our Cycle of Teacher Noticing Using the Framing, Attending, Interpreting, Shaping, and Responding Aspects

Framing contextualizes an instructional moment, pulling on the GTA's personal experiences of teaching and learning, pedagogical commitments, instructional identities, instructional team, and objectives for themselves or their students (Erickson *et al.*, 2011; Hammer *et al.*, 2005; Louie *et al.*, 2021; Russ and Luna, 2013; Sherin *et al.*, 2011). While framing has been considered, it has not been centred, including in Jacobs's (2010) study that acknowledged that "all aspects of teacher noticing are profoundly influenced by teacher's prior experiences as instructors, learners, knowledge of teaching, cultural backgrounds, instructional goals, knowledge of content, [*etc*.]." Thus, teaching influences framing, and framing influences teaching (Louie *et al.*, 2021) because frames guide the GTA's "attention within, interpretation of, and response to situations" (Hand, 2012, p. 251). This reciprocal relationship creates a bidirectional link or is embodied between each aspect and framing (Lau, 2010; Louie *et al.*, 2021; Russ and Luna, 2013) (Figure 2). Framing is increasingly important to explore GTAs' teacher noticing, given their positionality, limited power to influence course structure, (in)access to resources and professional development, and range of experiences in teaching and developing teacher identity. For GTAs, framing may link more to their experiences as students than their experiences as teachers (Schussler *et al.*, 2015). To understand how GTAs notice, we must also understand what instructional moments GTAs are drawn to (Sherin and Star, 2011) and how their framing dictates their interpretation of and response to these instructional moments (Robertson and Richards, 2017).

Our expanded and contextualized teacher noticing framework (Figure 2) guided our data collection and data analysis, addressing a gap in the literature on teacher noticing to holistically identify how GTAs' (as novice teachers) values influence their teacher noticing in the classroom. This operationalized framework led to conclusions and implications on supporting GTAs' experiences with and enactment of activities in the organic chemistry classroom.

Research Question

Our study explored how graduate teaching assistants (GTAs) taught a scaffolded, cooperative-learning case-comparison activity. The teacher noticing framework defines "teaching" as a teacher observing instructional moments (*i.e.,* attending) and connecting their observations to theory and practice (*i.e.,* interpreting, shaping, and responding) (Jacobs *et al.,* 2010; van Es and Sherin, 2021). Moreover, a teacher's pedagogical experiences, commitments, and identities frame their teaching (*i.e.,* framing) (Louie et al., 2021). Thus, guided by this framework, our research questions are:

1. How did chemistry GTAs attend to students' learning during the case-comparison activity, and how do they interpret, shape, and respond to what they attend to?
2. How did chemistry GTAs' framing influence their teacher noticing?

Positionality

We (IZ and DH) are researchers, educational consultants, and educators. Our roles are framed by our commitment to equitable teaching. IZ is committed to researching STEM learning experiences and teaching with subjectivity, empathy, and community, DH is committed to researching, teaching, and dreaming about just STEM learning spaces, and both are committed to training for equitable teaching. As researchers and educational consultants, we acknowledge that we hold more power than graduate teaching assistants (GTAs) do to enact these commitments. As GTAs ourselves, we acknowledge that we hold less power than faculty instructors and the institution do to enact these commitments. The graduate student's positionality (and our lived experiences) motivated this study. Moreover, a study design *for* graduate students *from* graduate students empowered us and, hopefully, our participants. Building relationships, we have known (Blue) Jay for 2 years, and DH has known Sparrow for 2 years. Therefore, we had established rapport, and our methodological decisions protected our relationships, where we limited data collection as much as possible outside of instructional responsibilities, and enhanced our study's trustworthiness, where we participated with Sparrow and Jay in observations and interviews. However, as graduate students, we brought unconscious biases and our own interpretations. GVS's role as a faculty instructor and MJS's role as an undergraduate student brought their own interpretations, complicating ours and, thus, strengthening our study's data analysis.

Methods

Our study was situated in the second-semester organic chemistry laboratory course (2 credits), a large-enrolment course (734 students) at a research-intensive (R1), Midwestern university. Typically, students enrol in the first-semester organic chemistry lecture and laboratory courses before, the second-semester organic chemistry lecture course during, and physical chemistry and biochemistry courses after they enrol in this course. Graduate students are hired as graduate teaching assistants (GTAs) and, therefore, are funded by graduate teaching assistantships. First-year graduate students receive a two-day teacher training during their summer orientation, but before receiving their teaching assignments.

Second-Semester Organic Chemistry Laboratory Course

This course was composed of a one-hour, once-a-week lecture that was taught by two faculty instructors and one administrative graduate student as well as a four-hour, once-a-week laboratory section that was taught by 26 GTAs. Each GTA taught two sections, and each section enrolled, on average, 18 students. This semester, the laboratory requirements were writing-intensive, and the syllabus stated,

> *"Writing supports critical thinking and is one of the best ways for you to connect laboratory results to organic chemistry concepts [...]. As instructors, we also like it because it helps us to better understand your thinking."*

The in-laboratory requirements included laboratory work and laboratory notebooks, which the GTAs assigned completion-based grades. Most of these laboratories were traditional laboratories (*e.g.,* the Wittig reaction), but two of these laboratories were "dry" laboratories (*i.e.,* our study's case-comparison activity). Out-of-laboratory requirements included one-page laboratory write-ups, which the GTAs assigned rubric-based grades, and three-page Writing-to-Learn assignments (Gupte *et al.*, 2021; Schmidt-McCormack *et al.*, 2019; Watts *et al.*, 2020; Zaimi *et al.*, 2024), which 20 undergraduate teaching assistants (UTAs) assigned rubric-based grades. There were no quizzes or exams.

Second-Semester Organic Chemistry Laboratory Instructional Team

The two faculty instructors, the one administrative graduate student, and the 26 GTAs formed the instructional team. The instructional team met once a week and emulated a *"teacher-learning community,"* also known as professional learning communities or communities of practice (Vescio *et al.*, 2008; Voelkel and Chrispeels, 2017). During these instructional meetings, they discussed: grading the past week's laboratory write-up and its rubric; preparing the next week's laboratory work and its materials (*e.g.,* slides, worksheets, and answer keys); recommending teaching practices (*e.g.,* classroom management strategies or questioning strategies); and practicing those materials and practices.

Case-Comparison Activity

A case comparison presents two "cases" and has asked, "Which reaction has the lower activation energy?" (Caspari *et al.*, 2018; Caspari and Graulich, 2019; Graulich and Caspari, 2021; Watts *et al.*, 2021), "Why do the reactions have different rates?" (Kranz *et al.*, 2023), or "Which molecules have a similar reactivity?" (Graulich *et al.*, 2019). These case comparisons have elicited multivariate reasoning (Alfieri *et al.*, 2013; Caspari *et al.*, 2018; Caspari and Graulich, 2019; Graulich and Caspari, 2021; Graulich and Schween, 2018; Haas *et al.*, 2024; Kranz *et al.*, 2023; Watts *et al.*, 2021). In order to do so, Caspari and Graulich (2019) have recommended scaffolded case comparisons, and Haas *et al.* (2024) has recommended a scaffolded, collaborative case-comparison activity. Building on this literature (Caspari and Graulich, 2019; Graulich and Caspari, 2021; Haas *et al.*, 2024; Watts *et al.*, 2021), we (IZ and GVS) designed a scaffolded, cooperative-learning case-comparison activity (Appendix 1) with three case comparisons and defined the learning objective as *"supporting students' multivariate reasoning.*[†]*"*

We (IZ and GVS) prepared a lesson plan and an answer key. During the instructional meeting, the administrative graduate student delivered these materials, in addition to prepared slides and recommended teaching practices. The administrative graduate student defined the GTA's role and the activity itself. Defining the GTA's role, the administrative graduate student shifted the GTA's role from a manager to a facilitator,

> *"Your role as a GTA is to act more as a discussion leader [facilitator]. You will answer students' conceptual questions about the activity and help guide their reasoning. [...] The case comparisons elicit multiple concepts. The [answer] key provides supporting as well as conflicting lines of reasoning. However, we do not expect students to be able to pull out all of the concepts mentioned in the [answer] key. Your job is to help students productively build at least one of the lines of reasoning presented in the [answer] key."*

Defining the activity itself, the administrative graduate student defined the activity as a scaffolded activity in terms of its design and as a jigsaw activity in terms of its implementation. This activity was a "scaffolded" activity that broke up the three case comparisons and the questions within a case comparison and *"built in difficulty."* They described, *"Students work through three case comparisons that build in difficulty. Each comparison builds upon students needing to leverage multiple chemical properties to get to the right answer."* Similarly, this activity was a "jigsaw" activity that divided a case comparison into "pieces" or cases and questions and *"split students into small groups."* They described, *"You split students into small groups to focus on learning their own task [case] or concept. Then, students with[in] each group teach what they have learned to students in other groups."* In order to reinforce these definitions, the GTAs practiced the activity, and they brainstormed students'

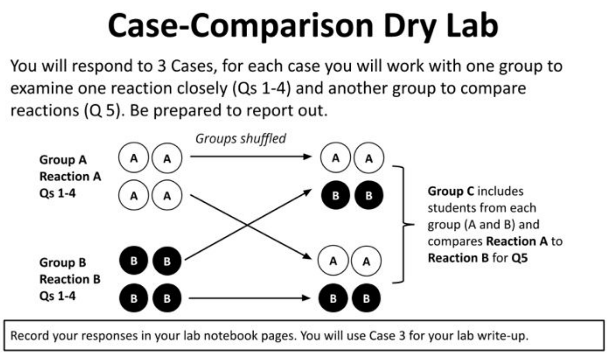

Figure 3 Case-Comparison Laboratory Slide This was one of the slides that the administrative graduate student gave GTAs in the instructional meeting and that GTAs presented students in the laboratory.

questions and discussed how they could answer them. The administrative graduate student challenged GTAs *"to ask more probing questions than leading questions."*

During the laboratory, the instructional team implemented the scaffolded case-comparison activity as a jigsaw activity (Figure 3). GTAs divided students into Groups A or Groups B, small groups with four students. Here, students examined one of the two reactions, where Group As examined Reaction A and Group Bs examined Reaction B (Appendix 1). Next, GTAs divided students into Group Cs, small groups with two Group A students and two Group B students (Appendix 1). Then, GTAs transitioned students from their small-group discussions to a whole-group discussion. This sequence repeated for Case Comparisons 2 and 3. Within a week, students submitted their laboratory notebooks, which GTAs assigned them completion-based grades, and students submitted their laboratory write-ups, which GTAs assigned them rubric-based grades (Appendix 2).

[†]The cooperative-learning implementation (*i.e.,* the jigsaw implementation) of the scaffolded case-comparison design delayed comparison, equipping students to be "experts" on one reaction with less functional groups before they compare both reactions with more functional groups. Multivariate reasoning is challenging, and we hoped that this delayed comparison scaffolded students' reasoning and supported their cognitive load. However, we acknowledge that this delayed comparison may have affected students' reasoning.

Case Profiles

Our study explored GTAs' enactment of a scaffolded, cooperative-learning case-comparison activity in a second-semester organic chemistry laboratory course. To do so, we paired the conceptual framework of teacher noticing (Jacobs *et al.*, 2010; Louie *et al.*, 2021; Russ and Luna, 2013; van Es and Sherin, 2021) and the methodological framework of a case study (Yin, 2018), where both frameworks required in-depth data collection with multiple data sources (*e.g.,* interviews, observations, fieldnotes, and documents) and data analysis. We recruited GTAs through email on a voluntary basis, and two GTAs volunteered, who thus became our cases. We obtained the Institutional Review Board's approval (HUM#00079234). We obtained the GTAs' consent, and the GTAs chose their pseudonyms, Sparrow and (Blue) Jay (Lahman *et al.*, 2015). Therefore, we employed a qualitative multiple case study, and Sparrow and Jay were our cases, defined by their teaching (*i.e.,* the phenomenon) and bounded by the activity (*i.e.,* the topic), its two-week implementation (*i.e.,* the time), and their classroom (*i.e.,* the space). We analysed our cases in isolation, not through comparative analysis.

Sparrow's Case Profile. At the time of our study, Sparrow was a graduate student in their second year of a chemistry doctoral program and in a chemical biology research group. Relatedly, Sparrow's professional aspirations were biochemist positions outside of academia, either in an industrial laboratory or a governmental laboratory. Sparrow's program funded their first year through an internal fellowship. Therefore, at the time of our study, Sparrow was a GTA in their first year of teaching. They taught the first-semester organic chemistry laboratory course in the fall semester, and they were teaching the second-semester organic chemistry laboratory course in the spring semester, which were outside of Sparrow's research expertise.

While Sparrow was working in a research-intensive institution and teaching in a large-enrolment course, they graduated from a primarily undergraduate institution (PUI). There, they had affirming, aspiring experiences in the organic chemistry courses, citing the small-enrolment courses, the major-specific sections, and the *"uncompetitive"* learning from classmates and the one-on-one teaching from the professor, and they became an undergraduate supplemental instructor (SI) for those courses. Sparrow enjoyed the professor's teaching style, especially his *"talk-through-your-thoughts"* facilitation and his patience. These learning experiences framed Sparrow's student-centred teaching, striving to create a relaxing learning environment and to be an affirming teacher. Sparrow mentioned learning the students' names and their interests, and we will mention playing Fleetwood Mac's *Rumors,* as Sparrow did during our observations.

Jay's Case Profile. At the time of our study, Jay was a graduate student in their first year of a research-based chemistry master's program. Jay's master's institution had also been their undergraduate institution. As an undergraduate research assistant, Jay had conducted research broadly related to STEM education and specifically related to motivation. Jay's master's research continued their undergraduate research. In order to fund their master's degree, Jay was serving as a first-year GTA. They had taught the first-semester organic chemistry laboratory course in the fall semester and were teaching the second-semester organic chemistry laboratory course in the spring semester. Providing unique insights into knowledge of students and content knowledge, Jay had taken these undergraduate organic chemistry courses and had served as an UTA for the second-semester organic chemistry laboratory course. However, Jay's professional aspirations were a career outside of academia in a health-related field.

Jay's teaching experience and professional aspirations influenced a teaching philosophy that prioritized students' skill development and transfer. Moreover, their research experience developed pedagogical knowledge, for example of relevance, motivation, and transfer, and supported their teaching philosophy. Furthermore, Jay's family, *"a family of educators,"* was a salient influence. Jay recalled conversations with family members on teaching practices (*e.g.,* setting an agenda and sharing it with students or sharing personal anecdotes) and explained how these conversations influenced their enactment of the instructional materials. These experiences framed Jay's student-centred teaching, striving to motivate students' skill development and transfer. In Jay's organic chemistry laboratory section, a student might see a picture of Jay's dog and hear the student-developed Spotify playlist.

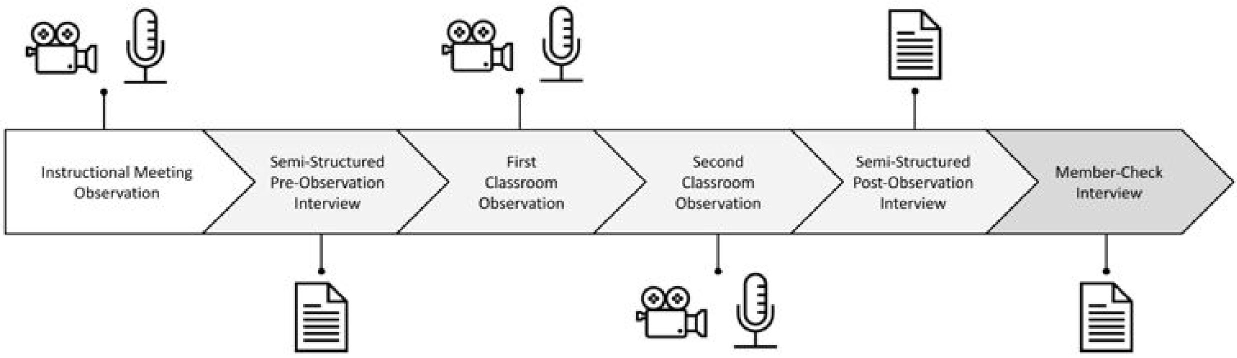

Figure 4 Data Collection Observations provided videos, which we analysed. The camera icon indicates that the data were video recorded, and the microphone icon indicates that the data were audio recorded. Interviews provided audios, which we then transcribed and analysed. The document icon indicates that the data were audio recorded and transcribed.

Data Collection

We collected three interviews, three observations, fieldnotes, and artifacts (*e.g.,* the syllabus, emails, slides, and materials) (Figure 4). First, we observed the instructional meeting, exploring how the administrative graduate student communicated the activity and delivered the materials as well as how they prepared and supported the GTAs. After this observation, within the one week, we conducted a semi-structured pre-observation interview. This 30-minute interview explored who the GTAs were and how they prepared to teach the activity. Questions included: “What courses have you taught?” “How is your relationship with the instructional team?” “Do you create your materials, or are the materials curated?” and “How have you prepared?” Because each GTA taught twice, we observed each GTA twice, exploring what changes the GTAs made within a section as well as what changes they made for the second section. After these observations, within the two weeks, we conducted a semi-structured post-observation interview. This 60-minute interview explored what the GTAs noticed, how they interpreted, and how they responded and included observation clips that cued these reflections. Questions included: “What is students’ reasoning?” “How did you facilitate students’ reasoning? “What teaching resources were you pulling from?” and “What teaching strategies were you pulling on?” Finally, after a few months, we conducted a member-check interview. The GTAs read their case profiles and the results and discussion, and they answered, “What parts feel aligned with your pedagogical experiences, commitments, and identities?” “What parts feel unaligned?” “What parts need additional or different information?” and “What parts should be removed?” The member-check interview enhanced our study’s trustworthiness (Cian, 2021), checking our analysis and interpretation of the GTAs’ teacher noticing cycles but also deepening our perception of the GTAs’ framing and extending the conversation on their teaching objectives. All observations were video recorded, either *via* Zoom (zoom.us) or *via* Swivl (cloud.swivl.com), and all interviews were audio recorded *via* Zoom (zoom.us) and transcribed *via* Otter.ai (otter.ai).

Data Analysis

We developed a qualitative coding scheme (Tables 1 and 2), where the teacher noticing cycle (Figure 2) is conceptualized by attending, interpreting, shaping, and responding and is situated in framing. Individually, we (DBH and IZ) coded Sparrow’s post-observation interview. Jointly, we met and negotiated consensus (Watts and Finkenstaedt-Quinn, 2021). We re-coded Sparrow’s post-observation interview and coded Jay’s post-observation interview. Our analysis involved: identifying these five codes in the interviews and observations; constructing teacher noticing cycles from these codes; and constructing vignettes from these teacher noticing cycles.

Our coding was conducted at the sentence level and produced sentences coded as attending, interpreting, responding, and framing, but not shaping (Table 1). Reviewing this coding, we found sections, either a long paragraph or a group of short paragraphs, that contained these four codes. Our memoing was conducted at the paragraph level and produced sections memoed as teacher noticing cycles (Table 2). Reviewing this memoing, we found a back and forth between interpreting and responding (*i.e.,* shaping), so we coded shaping at the paragraph level and incorporated shaping into the teacher noticing cycle (Table 2). These teacher noticing cycles informed how we coded and memoed the instructional meeting observation, the pre-observation interviews, the classroom observations, and the member-check interviews. The instructional meeting observation, the pre-observation interviews, and member-check interviews corroborated and complicated our perception of the GTAs’ framing, and the classroom observations corroborated our interpretation of their attending, interpreting, shaping, and responding. This triangulation (Yin, 2018) produced “rich, thick” teacher noticing cycles.

We chose two teacher noticing cycles, one that best exemplified and celebrated Sparrow’s teaching and one that best exemplified and celebrated Jay’s teaching, and we wrote them as “small stories” (Josselson and Hammack, 2021) or vignettes. Moreover, we combined the shared story of Sparrow’s and Jay’s changes from implementation to enactment into a third vignette or the composite case. We present these vignettes in the results and discussion. We conceptualize the teacher noticing cycle as a story arc, and this storytelling (Josselson and Hammack, 2021) provides a view into the classrooms of two chemistry GTAs. Without comparison, these vignettes serve as a novel way of reporting on chemistry GTAs’ enactment of activities in the classroom.

Table 1 Teacher Noticing Coding on the Sentence Level These examples are from one of Sparrow’s teacher noticing cycles (middle row) and one of Jay’s teacher noticing cycles (bottom row).

Aspects	Framing	Attending	Interpreting	Responding
Description	The GTA contextualizes an instructional moment – pulling on their personal experiences of teaching and learning and instructional identities as well as pulling from their instructional team and objectives for themselves or their students.	The GTA observes an instructional moment (*e.g*, student talk, student work, student resources, group placement, student answers, student questions, or students themselves), or the GTA doesn’t.	The GTA interprets an instructional moment *(e.g.,* student progression, student engagement, and student understanding) – pulling out their pedagogical reasoning and pulling on their content knowledge, pedagogical knowledge, and instructional experiences.	The GTA responds to an instructional moment (*e.g*., teaching practice, classroom management, time management, or instructional resources), or doesn’t. Responding can be planned, impromptu, tacit, or proposed.
These examples are from one of Sparrow’s teacher noticing cycles. We showed Sparrow seating charts, and we asked them, *“How did you group* students*? How did*	*“With the case-comparison [activity], you wanted,* ***everyone was supposed to****, kind of* ***contribute****. [...] You're trying to get people around, to utilize these end*	*“In like, this seating configuration like,* ***there's*** *just a lot* ***less conversation when people were*** *like,* ***all in a line*** *[...]. [...]* ***This group****, they were, they* ***would***	*“But it wasn't, it didn't feel like... [...] It was less like,* ***I felt like less full-group conversation****. [...] It definitely felt like that worked a*	*“Uh. But in the future, I think, if I were to run this again* ***I might****, like might label* ***the ends****, be like,* ***‘meet here.’*** *Um. Or! Another thing that would be great with this type of*

the group's placement affect their participation?" The aspects were coded in the post-observation interview.	*spots, [...]* **but** *I was, I was like,* ***I'm not gonna force it****, and you can sit where you want to sit. [...] I didn't want to like, disrupt everyone once they're already working."*	***cluster more in*** *like,* ***twos and threes****, I think. [...] When they were in the rows like, they, I think* ***they were still talking to people next to them*** *a little bit more."*	*little bit better when they had like, these sort of arrangements."*	*activity is, I mean, I know it's not possible, I guess, because we have like so many lab sections, but* ***I think this type of activity in****, have like* ***one of those*** *like, more* ***collaborative learning spaces with*** *like,* ***clustered tables*** *like, I think* ***would go a lot more smoothly****."*
These examples are from one of Jay's teacher noticing cycles. We asked Jay about their experience enacting the learning objectives of the case-comparison activity, and we asked questions, such as *"How did you facilitate students' reasoning in the activity?"* The aspects were coded in the post-observation interview.	*"Because* ***I don't believe in this idea of*** *like,* ***not telling students whether they're right or not****, I think that's absurd."*	*"Probably the same way, like* ***I handled questions****.†"*	*"And* ***if they gave me a good explanation****." [...] "But* ***if they were a little off****."*	***"I would say like, 'Alright. What do you think?'*** *And they would give me an answer. And then I would say, 'Okay. Why?' And then ask for some sort of explanation." [...]* ***"I'd be like, 'Yep.'"*** *[...]* ***"It'd be like, consider this and then walk away****. And let them, let that cook a little bit."*

†We found that attending could be participant-led attending or interviewer-led attending, depending on the methods. In the semi-structured pre-observation interview protocol, we directed Jay to attend to students' reasoning (*i.e., "How did you facilitate students' reasoning in the activity?"*), and they compared attending to students' reasoning to attending to students' questions (*e.g., "Reasoning is, is not just being able to give an answer, but also a why […]"*.) Consequently, this interview quote captured interviewer-led attending.

Table 2 **Teacher Noticing Coding on the Paragraph Level** These examples are from one of Sparrow's teacher noticing cycles (middle row) and one of Jay's teacher noticing cycles (bottom row).

Aspects	Shaping	Teacher Noticing Cycle
Description	The GTA creates instructional moments (*e.g.,* asking a series of probing questions) that elicit students' reasoning.	The teacher noticing cycle conceptualizes that a GTA attends to an instructional moment, interprets the instructional moment, and responds to the instructional moment (*i.e.,* the AIR aspects). However, holistic teacher noticing cycles may capture shaping and will capture framing.
These examples are from one of Sparrow's teacher noticing cycles. We showed Sparrow seating charts, and we asked them, *"How did you group students? How did the group's placement affect their participation?"* The aspects were coded in the post-observation interview.	Shaping was not coded.† This teacher noticing cycle involved classroom management, not a student-teacher interaction.	*"With the case-comparison [activity], you wanted,* ***everyone was supposed to****, kind of* ***contribute****. [...] You're trying to get people around, to utilize these end spots, [...]* ***but*** *I was, I was like,* ***I'm not gonna force it****, and you can sit where you want to sit. [...] I didn't want to like, disrupt everyone once they're already working." (Framing) "In like, this seating configuration like,* ***there's*** *just a lot* ***less conversation when people were*** *like,* ***all in a line*** *[...]. [...]* ***This group****, they were, they* ***would cluster more in*** *like,* ***twos and threes****, I think. [...] When they were in the rows like, they, I think* ***they were still talking to people next to them*** *a little bit more." (Attending) "But it wasn't, it didn't feel like... [...] It was less like,* ***I felt like less full-group conversation****. [...] It definitely felt like that worked a little bit better when they had like, these sort of arrangements." (Interpreting) "Uh. But in the future, I think, if I were to run this again* ***I might****, like might label* ***the ends****, be like,* ***'meet here.'*** *Um. Or! Another thing that would be great with this type of activity is, I mean, I know it's not possible, I guess, because we have like so many lab sections, but* ***I think this type of activity in****, have like* ***one of those*** *like, more* ***collaborative learning spaces with*** *like,* ***clustered tables*** *like, I think* ***would go a lot more smoothly****." (Responding)*
These examples are from one of Jay's teacher noticing cycles. We asked Jay about their experience enacting the learning objectives of the case-comparison activity, and we asked questions, such as *"How did you facilitate students' reasoning in the activity?"* The aspects were coded in the post-observation interview.	***"I would say like, 'Alright. What do you think?'*** *And they would give me an answer. And then I would say, 'Okay. Why?' And then ask for some sort of explanation." (Responding) "And* ***if they gave me a good explanation****." (Interpreting) "****I'd be like, 'Yep.'****" (Responding) "But* ***if they were a little off****." (Interpreting) "****It'd be like, consider this and then walk away****. And let them, let that cook a little bit." (Responding)*	*"Probably the same way, like* ***I handled questions****." (Attending) "****I would say like, 'Alright. What do you think?'*** *And they would give me an answer. And then I would say, 'Okay. Why?' And then ask for some sort of explanation." (Responding) "And* ***if they gave me a good explanation****." (Interpreting) "****I'd be like, 'Yep.'****" (Responding) "Because* ***I don't believe in this idea of*** *like,* ***not telling students whether they're right or not****, I think that's absurd."* (Framing) *"But* ***if they were a little off****." (Interpreting) "****It'd be like, consider this and then walk away****. And let them, let that cook a little bit." (Responding)*

†In constructing the teacher noticing cycles, we found that the five codes (*i.e.,* framing, attending, interpreting, responding, and shaping) did not all have to be captured or captured in a specific cyclical pattern.

Limitations

We acknowledge that the case study methodology is a balance of affordances and limitations. Our cases were defined by the graduate teaching assistants' (GTAs') teaching (*i.e.,* the phenomenon) and bounded by the case-comparison activity (*i.e.,* the topic), the activity's two-week implementation (*i.e.,* the time), and the GTAs' classroom (*i.e.,* the space) (Yin, 2018). Considering the topic, we designed a single activity, and we implemented the activity in a single course at a single institution. Considering the time, we collected data in two weeks and requested only one-and-a-half hours of interviewing in addition to nine hours of observing. Graduate students have time-intensive schedules, and we respected their schedules and considered participant fatigue, as GTAs ourselves. Furthermore, due to a small participant pool and the quick turnaround time between recruitment and data collection, we recruited two participants. Both participants had a respect for and an interest in teaching, but not a professional interest or as a career path. Many GTAs consider or pursue careers outside of academia (Ganapati and Ritchie, 2021), and these cases highlight the experiences of GTAs who must teach (*i.e.* funding) and will pursue careers outside of academia. However, these cases do not capture the experiences of GTAs who want to teach and will pursue careers in education (*i.e.,* professorships or K-12 positions). Case studies "are generalizable to theoretical propositions and not to populations or universes" (Yin, 2018, p. 20). Therefore, we view this qualitative methodology as a way to explore lived experiences with in-depth insights and pedagogical partnership, in ways large-*n* studies could not.

We paired the methodological framework of a case study (Yin, 2018) and the conceptual framework of teacher noticing (Jacobs *et al.*, 2010; Louie *et al.*, 2021; Russ and Luna, 2013; van Es and Sherin, 2021). Research recommended various methods to capture teacher noticing (Amador *et al.*, 2021; Sherin *et al.*, 2011); however, some methods elicited more information on some aspects of teacher noticing than other methods did. Because we selected observation clips to show the GTAs in the post-observation interviews, we directed their attending. While this elicited less information on GTA's attending, it enabled us to elicit more information on the GTA's interpreting, shaping, and framing. We privileged these aspects, which have been less reported on than attending has been.

We propose that subsequent studies take a longitudinal approach and explore unique cases. Still, the conclusions of this study add to teacher noticing and chemistry education because the purpose of this study was to highlight how chemistry GTAs notice during an activity. Given these limitations, we find that this study has important implications for supporting chemistry GTAs, and further research should be done to study this population.

Results

This section provides three vignettes: the first vignette is from Sparrow's case; the second vignette is from (Blue) Jay's case; and the third vignette is from Sparrow's and Jay's composite case. Exemplifying the teacher noticing cycle, we describe what Sparrow and Jay attended to, how they interpreted, how they shaped, and how they responded to what they attended to. Furthermore, we discuss how Sparrow's and Jay's learning experiences, teaching experiences, and teaching philosophies inform their teaching, exploring and emphasizing framing. We expose the tension and resolution between learning objectives (*i.e.,* objectives set by the instructional team for students) and teaching objectives (*i.e.,* objectives set by the graduate teaching assistants [GTAs] for themselves and their students) (Zotos *et al.,* 2020). Specifically, learning objectives are objectives that are focused on students' learning outcomes and that are set by faculty instructors and, in this activity, researchers. Typically, GTAs are not the designers and implementors, but they are the enactors who may hold similar or different learning objectives. Denoting GTAs' positionality and their relative (lack of) curricular power, teaching objectives are objectives that are focused on students' learning outcomes but that are set by GTAs.

Sparrow's Case: "Turning Their Brains on"

The instructional team described the case-comparison activity's learning objective to their GTAs in the instructional meeting as developing students' multivariate reasoning. Pulling on these directions and reflecting on the activity, Sparrow described this activity's learning objective to us in the post-observational interview as *"separat[ing] it [the problem] into its component parts*" and *"put[ting] them back together."* Sparrow's description captured a problem-solving process, where the students *"separated"* or deconstructed the problem and then *"put back"* or synthesized an answer. The activity scaffolded this problem-solving process, starting with questions on structural features, continuing with questions on chemical and physical properties and questions on changes, and ending with "Which reaction occurs faster?" (Appendix 1). Sparrow's description matched the instructional team's description, as did the learning objectives.

Although the learning objective was developing students' reasoning, Sparrow's teaching objective was creating a relaxing learning environment. Sparrow described their teaching objective, *"I want it [the laboratory] to be relaxed, [...] [for students to] feel like they can take risks and ask questions and yeah."* Sparrow's description emphasized a *"relaxed"* or low-stress, low-stakes learning environment. The instructional team did not direct this objective, but the course syllabus stated supportive cognitive and affective learning practices, such as collaboration, metacognition, and academic belonging. Historically, organic chemistry courses have had high attrition rates, and they have been high-stress, high-stakes learning environments (Gibbons *et al.*, 2018), also known as "gateway" or "weed-out" courses (Collini *et al.*, 2023; Gupta and Hartwell, 2019). However, Sparrow described their learning experiences: Sparrow felt that the organic chemistry courses in their PUI had a *"really great environment,"* so they *"felt safe*" and *"ended up pursuing a degree in chemistry."* Moreover, Sparrow contrasted their learning experiences to their students' learning experiences,

> *"I've talked to some students individually who like, really underestimated themselves and their abilities. They're like, 'Everyone here sounds smarter than me.' I think that that adds like, a level of anxiety to a lab section that can be just, kind of detract from your ability to like, focus on the actual science [...]."*

Countering *"anxiety-adding"* learning environments, Sparrow's learning and teaching experiences framed their teaching objective, creating a relaxing learning environment (Figure 5). This learning environment would foster students' confidence, as Sparrow intended, but also could support their reasoning or *"turning their brains on,"* as Sparrow reflected in the post-observation interview.

Sparrow's learning and teaching experiences informed their framing, which, in turn, informed their teaching. One of these instructional moments was scaffolding the problem-solving process, an important instructional moment that we repeatedly captured in our observations. This is exemplified in an observation clip, where Sparrow transitioned the small-group discussions into a whole-group discussion for Case Comparison 2. Sparrow moved from one of the tables in the back of the laboratory to the computer or the "front" of the laboratory. Looking from left to right, Sparrow asked, *"What is the hybridization of that carbonyl carbon?"* A student answered,

"sp^2." Sparrow attended to this student's answer (Figure 5) and, because the student's answer was correct and they thought that students could *"handle bigger conceptual jumps,"* responded with *"Yeah! sp^2!"* and scaffolding questions (Figure 5). Sparrow asked those questions, and the same student answered these questions:

Sparrow (looks from left to right): "*What shape is that molecule?"*

Sparrow (pauses for 4 seconds and looks from left to right): *"Is it two-dimensional or three-dimensional?"*

Student: "*Two."*

Sparrow (looks at the student): *"Yeah! Two! Because it's planar."*

Sparrow (looks right): "*What is the hybridization of that tetrahedral product?"*

Student: *"sp^2."*

Sparrow (looks at the student): *"Yes! sp^2! It's not a trick question. I pinky promise."*

As students continued to *"handle bigger conceptual jumps"* and Sparrow attended to those, Sparrow responded to them and continued to ask scaffolding questions. Different students started to participate. Wrapping up, Sparrow asked:

Sparrow (looks from left to right): *"If you thought Y was the faster reaction, raise your hand!"*

All Students (do not raise their hands)

Sparrow (looks from left to right): *"If you thought Z was the faster reaction, raise your hand!"*

All Students (raise their hands)

Sparrow (looks from left to right): *"Ay!"*

Sparrow celebrated and transitioned from the whole-group discussion to the small-group discussions for Case Comparison 3.

This observation clip captured Sparrow's attending to students' answers and Sparrow's responding to them with scaffolding questions, but the post-observation interview probed Sparrow's interpreting. In the post-observation interview, we showed Sparrow this observation clip, and we asked them, *"How did you facilitate students' reasoning?"* Attending to students' answers (Figure 5), Sparrow commented, *"I think in [...] that clip absolutely like, everyone knew the answers. [...] I just wanted people to sort of be confident in them [their answers] and speak up."* We learned that Sparrow did attend to students' answers (*e.g., "everyone knew the answers")* (*i.e.,* the learning objective), but they also attended to students' confidence (*e.g., "be confident [...] and speak up")* (*i.e.,* their teaching objective), in order to holistically interpret students' knowledge (Figure 5). Thus, responding to students' confidence with scaffolding questions (Figure 5), Sparrow explained,

> *"I tried to like, simplify it and start like, asking kind of like, probing- leading questions [...]. Then I tried to kind of like, [...] increase it in complexity. Trying to sort of… [ask] escalating questions. So hopefully they have like, a couple correct answers under their belts and feel a little bit better about maybe con-doing some conjecture."*

Sparrow reflected that this response fostered students' confidence, and, because of this relaxing learning environment, supported students' reasoning, or *"doing some conjecture,"* as Sparrow said here, and *"turning their brains on,"* as Sparrow said before. Sparrow elaborated, *"If I think they can handle like, a bigger conceptual jump. Then I'll try for that."* Thus, if the interpretation is a correct *or* confident answer, then the response is a harder question. However, Sparrow elaborated, "*If they get lost. Then I'll go back and just kind of start over. [If] they get to a question that they're confused by or I know that- I realize that they're confused by. Then I can re-explain [that] to them."* Thus, if the interpretation is an incorrect *or* unconfident, *"confused"* answer, then the response is an easier question. This bouncing between interpreting and responding is shaping (Figure 5), and Sparrow's shaping facilitated their attending to students' answers (*i.e.,* the learning objective) and students' confidence (*i.e.,* Sparrow's teaching objective). Therefore, Sparrow's teaching objective supported the activity's learning objective.

Notably, this shaping depended on Sparrow's tacit knowledge of students. Sparrow clarified in the member-check interview,

> *"I like, know students. And I know when they're, you know, like, when they're showing up. And when [...] they're capable of answering harder questions. So [I know] how [to] like, push*

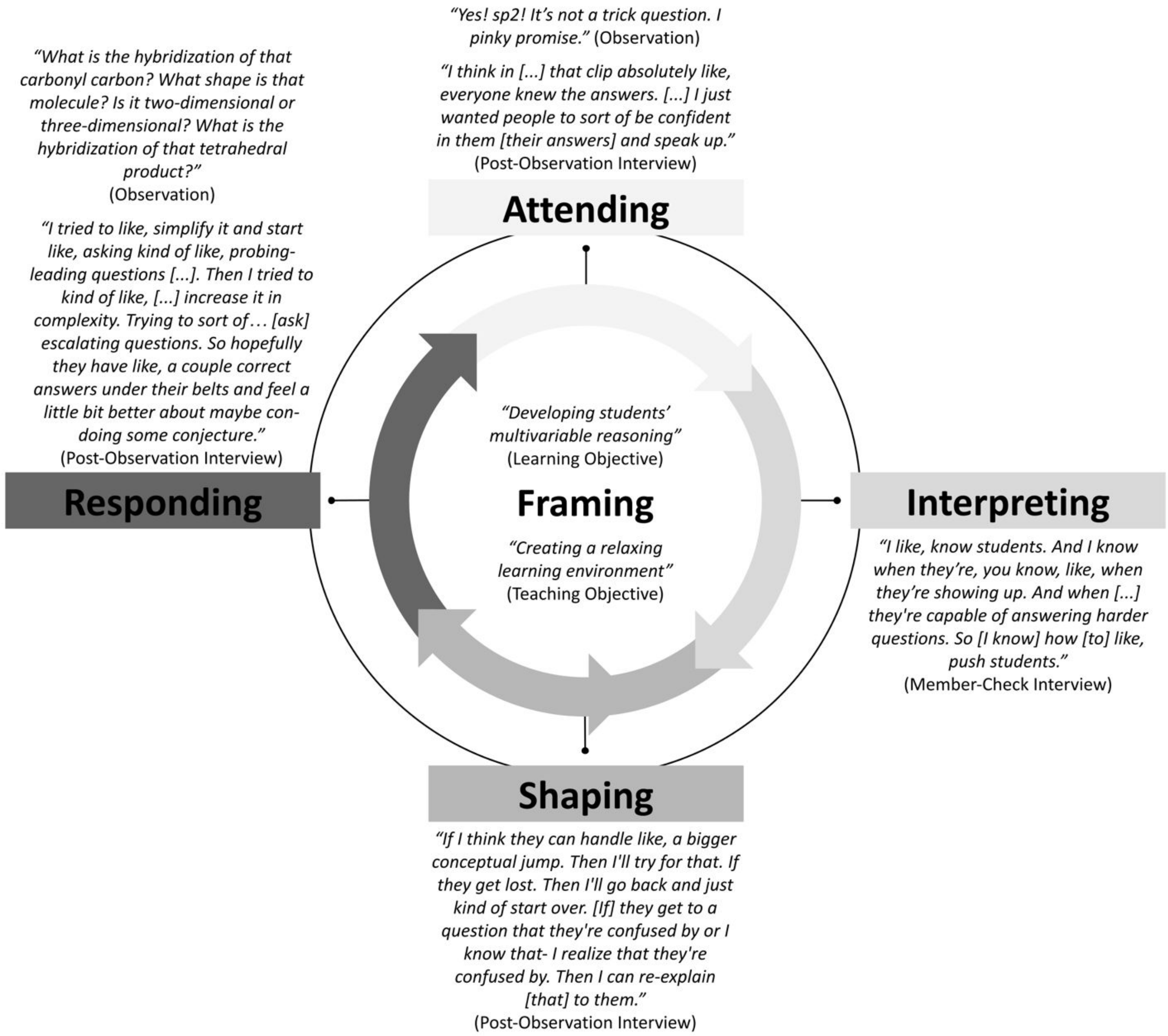

Figure 5 Sparrow's Case Mapped onto the Teacher Noticing Cycle The teacher noticing cycle is conceptualized by attending (the lightest grey arrow), interpreting, shaping (the bidirectional arrow), and responding (the darkest grey arrow), and this cycle is situated in framing (the white circle).

students."

However, shaping had not always been present in Sparrow's teaching. In the pre-observation interview, we asked Sparrow, *"How has your teaching changed?"* Comparing their teaching from the fall semester to the spring semester, Sparrow described,

> *"[...] I'm better at knowing when people are trying to get through the lab without actually like, turning their brain on [...]. I try to answer questions in a way that it's more like, guiding questions [...]. [...] So it's not about like, giving the information to them as quickly as possible. It's like, can you like, can we like, think through this a little bit and take the time to do that? [...] Just kind of like, kind of asking back until I find where they've [the students] kind of like, lost the plot. [...] I think I answered questions more directly in [the first-semester organic chemistry laboratory]."*

Sparrow's teaching changed, focusing less on managing the classroom and answering questions and more on asking questions and engaging students. Sparrow cited the courses themselves and how they affected students' knowledge: *"Because of how [the first-semester organic chemistry laboratory] was structured, [students] [...] would like, show up to the TLC lab, with no understanding of TLC, right beyond [...] the pre lab."* Studies have established that teaching develops with experience and expertise (Berliner, 2004), and Sparrow has practiced interpreting and responding in the moment. Studies have also established that teaching develops in teacher-learning communities (Vescio et al., 2008; Voelkel and Chrispeels, 2017), and the instructional team structured their instructional meetings as these communities. Reflecting on these instructional meetings in the pre-observation interview, Sparrow commented, *"Instructional meetings have been helpful [...] because that brings up [...] trickier questions or things that are harder to answer in the moment."* Similarly, reflecting on these instructional meetings in the post-observational interview, Sparrow described these instructional meetings as *"helpful"* and the GTA-GTA discussions as *"resources."* Sparrow's vignette highlights that structures outside of GTAs' responsibilities (*i.e.,* instructional meetings and learning objectives) inform GTAs' teaching, as do practices within their power (*i.e.,* teaching objectives).

Jay's Case: "Testing Your Brain"

Building upon the instructional team's learning objective of developing students' multivariate reasoning and connecting to Sparrow's teaching objective of creating a relaxing learning environment, Jay's teaching objective was to find relevance to connect to students' problem-solving skills (Figure 6). This vignette captures a significant event for Jay, where they *"test[ed]"* a student's brain, providing insight into how they approached answering advancing and assessing student questions. In the post-observation interview, Jay reflected on student talk, student work, and student questions. Specifically, Jay described how they attended to student engagement,

> *"In this activity, I looked at if they were engaged in conversation with their peers, consulting notes, maybe they would ask me a question or maybe a follow up question that wasn't necessarily directed to the activity but was more tangentially related, but ultimately, like be, help them be successful later on in like a different chemistry course. I looked for those things, I guess, for students that were engaged."*

Jay identified attending to various ways students might engage with the case-comparison activity. Jay elaborated on their interpretation of students' questions, describing some questions as "*tangentially related"* to the content of the activity, but they qualified this with an interpretation of how these "tangential" questions *"ultimately… help them be successful later on in like a different chemistry course."* When probed further on how Jay interpreted and responded to student questioning they attend to, they mentioned,

> *"So if they ask me a question, I usually respond with like questions and a scaffold. So I'll be like 'Okay, let's walk it back. What is this? Okay. Well. What do you know about that?' And so you scaffold almost like a downward triangle funnel, scaffold funnel towards the answer. And that's usually better than me just telling them outright."*

Jay elaborated on a teaching practice they enacted: scaffolding students' questions to promote problem-solving. This is a teaching practice we observed several times in the audiovisual data. When a student asked a question to Jay, their response was to seek out more information about how the student was thinking about the problem conceptually. Similar to Sparrow, Jay scaffolded students' questions to break down large concepts (Figure 6). Additionally, Jay asked probing questions to elicit students' conceptual understanding by intentionally continuing questioning conversations. As captured in the classroom observation, Jay attended to students' questions and responded by asking the student a series of questions:

> (A student calls Jay over through a hand raise and eye contact. Jay quickly notices and jogs over.)
> Student: *"Why would it attack this carbon over everything else?"*
> Jay: *"Hm. Why do you think?"*
> Student: *"I was assuming… It is sterically hindered?"*
> Jay: *"Yeah."*
> Student: *"So a resonance contributor."*
> Jay (points to a different functional group): *"Yeah! Testing your brain: Why not down here?"*
> Student: *"Because there's no resonance contributor."*

In the above quote from the audiovisual data, the student asked a question, and Jay turned the question around to reveal their thinking. When the student's answer was interpreted by Jay as the correct direction of thinking, Jay's response was an encouraging "*Yeah*." As the student continued to identify implicit features of the problem, Jay responded and asked a question to elicit student thinking about the different variables in the problem, creating an opportunity to understand the student's conceptual knowledge in new contexts. This is an example of how Jay shaped their noticings of student interactions, creating new opportunities to interpret students' conceptual knowledge, thereby continuing opportunities to respond to student sensemaking (Figure 6). The idea of "*testing your brain*" highlights Jay's goal to introduce new contexts for students to apply these problem-solving skills and conceptual knowledge, and they created opportunities to do so in one-on-one conversations with students.

The pedagogical strategy, of asking questions, connects to Jay's overarching goals for their students. Jay's overarching goal for their students is that they "*want them to grow as thinkers*" beyond the learning objectives and assessments of this one course. In the pre-observation interview, we asked how Jay prepared for teaching the case-comparison activity, revealing how their goal influenced planned responses. They responded,

> *"I want them to see this class as something other than just a weed-out course, I want them to learn something, I want them to- even if it's not about chemistry… I want them to have like, the thinking skills, the analytical skills, that are transferable to novel situations for them. So if they come across something in a different class or in their career, and they don't know how to solve it, I'd like them to have these thinking skills that they can apply that they learned in this class, about how to think about things, how to think about things scientifically that they can carry forward."*

Jay's elaborations on their teaching objective of finding relevance and motivation highlight an underlying goal for students, to develop *"thinking skills, analytical skills, that are transferable to novel situations."* Jay saw the problem-solving, skill-building within the case-comparison activity as preparation for new professional or disciplinary contexts. Jay also aimed to support students' learning within the "*gatekeeping*" or "*weed-out*" classes that Sparrow mentioned. This is an underlying teaching objective aimed at supporting student success in gatekeeping courses, such as introductory organic chemistry.

We saw Jay's teaching objectives enacted, again, during the classroom observation. Jay often approached groups to check in on student work and initiate conversations with students as well as consider time management. Here, Jay approached a group and they began the conversation by stating what question they were on and where they might need help:

> Student: *"We were kind of discussing like Question 4."*
> Jay: *"Question 4?"*
> Student: *"We- we knew the reason behind it but like not really sure how we would put it into words."*
> Jay: *"That's always tough - knowing it in your head but not knowing how to externalize it."*

The students discussed that they were struggling to put their ideas into words, and Jay acknowledged students' feelings in a relaxed tone. Chemistry meaning-making requires integrating a variety of chemical jargon and argumentation strategies, which can be a difficult and frustrating challenge, especially for Eng+ (English as an additional language) students (Charity Hudley and Mallinson, 2018; Deng *et al.*, 2022; Sengupta-Irving and Vossoughi, 2019). Jay empathized with this situation, validating that not having the words is frustrating. This empathetic response lends itself to Jay's framing, as a GTA who had experienced the same course as a student, not long ago. Jay's response to students validated the emotional struggle, and they continued the conversation with the group to help students "*put it into words*." The students began to discuss resonance structures that they remembered from their lecture, including open-shell carbon resonance structures. Jay shaped, by asking questions about their thinking, and then responded by asking questions about broader patterns of problem-solving in organic chemistry:

> Jay: *"So why is that open-shell carbon not the most stable or… most um… major resonance contributor?"*
> Student 2: *"Isn't it because a major resonance contributor… doesn't it go like… Isn't having open shell like the least major resonance [structure] in general?"*
> Jay: *"Yeah. Disregard rules for a second. What happens if you have a carbocation? Are you stable or unstable?"*
> Student 2: *"Unstable?"*
> Jay: *"Unstable. Nature always orders itself toward stability."*
> Student 2: *"Uh huh."* Jay: *"No matter what, it's always going for things that are not reactive and very stable."*
> Student 2: *"Okay."*

Jay shaped by trying to gauge student understanding of stability and resonance. The student responded to this question with an unsure answer, which Jay responded to by asking the student to disregard rules. They then constructed a new context for the student to work within, looking at what the stability might look like with a carbocation. Jay then used this as an opportunity to bring in a heuristic in organic chemistry, that everything moves toward stability. Heuristic use in organic chemistry has been challenged by those who favour mechanistic reasoning to approach conceptual problem-solving (McClary and Talanquer, 2011; Talanquer, 2014), but, due to the demanding conceptual nature of learning organic chemistry, some heuristics may be useful for novice learners to identify patterns of problem-solving (Graulich *et al.*, 2010). By modelling pattern recognition through heuristics, Jay addressed their teaching objective of supporting students' problem-solving skills to connect to broader goals for learning outside of organic chemistry-specific topics.

Jay's pedagogical strategy of asking follow-up questions was influenced by their teaching objectives and framing. The teaching objective of finding motivation and relevance between the students' goals and the assigned activities led to the enactment of relational interactions centred on relevance for the students (Figure 6). In the post-observation interview, we asked Jay if they noticed students struggling to participate with the activity, and they responded, "*I don't know if it came up super often*." However, they continued, mentioning a proposed or planned interpretation and response for encouraging participation through this connection-building,

> *"If it did, though… It'd be like 'Yep. I understand this is not for everyone,' I think. And then I would kind of rationalize why I think it's helpful to, to engage in this activity. And be like, 'You want to do well in the class, because you can go into dental school, like. You should probably know how to do this stuff to at least just get through the class and get done with it.' And then also a kind of like, you know, thinking skills that you'll develop here are not just applicable to [Organic Chemistry 2 Lab]; you can take those elsewhere with you."*

Jay's position and values, the framing, influenced the development of this teaching objective. Holding a teaching objective highlights the unique position of GTAs as near peers to undergraduate students (especially in Jay's case as an alum of this particular school) and a mentee with limited power to make curricular decisions to faculty members. In this case, Jay's teaching objective is highly influenced by their personal experiences and beliefs about teaching and learning (Figure 6). These epistemological resources are activated in the teaching setting, leading to changes in the enactment of the activity in the classroom setting, as captured through teacher noticing (Hammer *et al.*, 2005; Hand, 2012; van Es and Sherin, 2021).

Sparrow's and Jay's Composite Case: Being "Facilitators" and "Resources" and "Zookeepers," Oh My!

The change from implementation to enactment in a classroom has

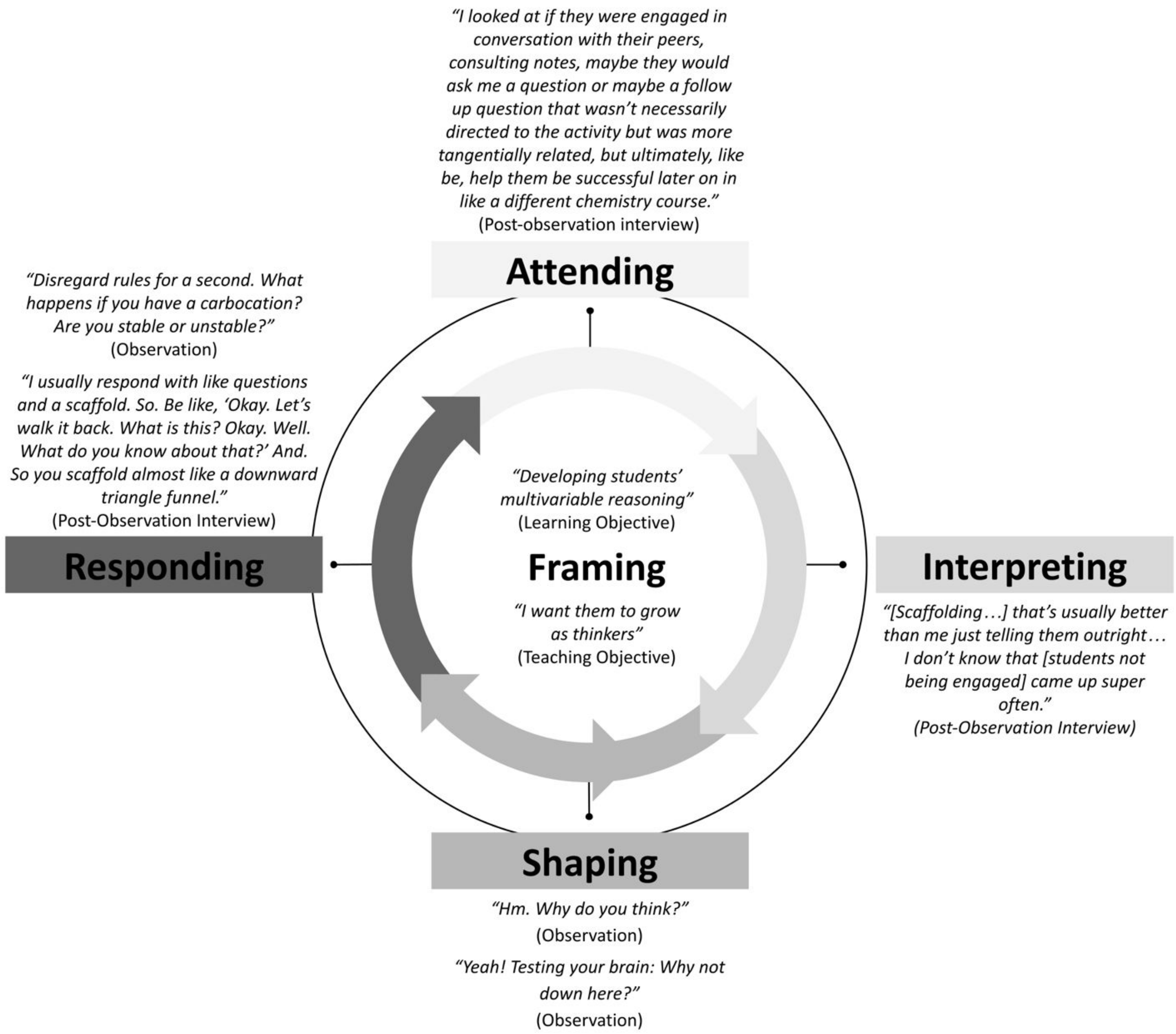

Figure 6 Jay's Case Mapped onto the Teacher Noticing Cycle The teacher noticing cycle is conceptualized by attending (the lightest grey arrow), interpreting, shaping (the bidirectional arrow), and responding (the darkest grey arrow), and this cycle is situated in framing (the white circle).

power and could develop a teacher identity. This composite case combines two impromptu responses, wherein Jay and Sparrow exhibited enactment. While we perceive that Jay and Sparrow, GTAs, are teachers, they perceived that they are not.

When we conducted Jay's first classroom observation, we observed that Jay changed the activity from a whole-group discussion to a gallery walk. Facilitating a whole-group discussion was challenging, as few students participated and answered (or asked) questions. Jay approached IZ and DH and said, "*It's like pulling teeth… I've gotta think of a better way to do this.*" Jay reflected how they would modify the whole-group discussion,

Jay: "I should have had them write things down on an index card and bring them up to me and read them aloud."

IZ: "That would have been fun."

Jay: "Or like a text your answer in and it shows it on the board." (gestures to the projector screen in the middle of two whiteboards)

Jay: "Ugh… Why do I think of these things now? This is why I'm a bad [GTA]." (huffs and walks away with their hands on their head)

IZ: "It's not too late. You have two more cases."

Jay considered their options, and, after the small-group discussions for Case Comparison 2, they enacted a gallery walk. Jay had students come up to the whiteboard and *"write down some ideas."* Next, Jay had students read and review the board, like a "gallery." Then, Jay facilitated the whole-group discussion, referring to the written ideas on the whiteboard instead of asking for students' verbal answers. However, while Jay modified the discussion in order to adapt to their class's engagement with another active-learning strategy, they maintained that they are not *"a good teacher"* or a *"bad [GTA]."*

Similarly, we noticed that Sparrow changed their instructions from the first classroom observation, where students should be discussing, to the second classroom observation, where students should be discussing *and* picking a spokesperson. Sparrow explained, "*That was what [the peer-GTA] did [...] because [they were] also having people, trouble [getting people] to speak up*." Sparrow explained how this peer-GTA changed their teaching throughout the post-observation interview. Specifically, the peer-GTA found a pKa table, and Sparrow *"emailed that to everyone because [they] thought it would be helpful for everyone to have the same one, regardless of like, whether or not it's the best one."* Generally, they would *"talk about [their] jobs"* and share teacher talk. Sparrow claimed these GTA-GTA discussions between sections as *"resources,"* in addition to those GTA-GTA discussions in instructional meetings. Sparrow's perception of instructional teams as "resources" parallels their perception of their instructional role. Sparrow defined their instructional role *as "a resource to them [students],"* not necessarily as a teacher.

Describing their instructional role, Jay described themselves as *"a bad [GTA]"* and, moreover, "*feel[ing] more like a zookeeper than a teacher.*" Their reflective moment in the classroom echoed Sparrow's reflection in the post-observation interview. Ruminating on their instructional power, Sparrow mused, *"I guess I prefer a more casual teaching style. [...] I'm not, I don't have as much power like, within the course, [so] it feels okay to be a little bit more informal."* Combined, the cases capture an authentic negotiation of power and formation of teacher identity for Chemistry GTAs.

Discussion

Graduate teaching assistants (GTAs) hold a complex positionality, as employees to the institution, research mentees and students to faculty members, and research mentors and teachers to undergraduate students. As teachers, GTAs teach laboratory and discussion sections with 20-30 undergraduate students and provide personalized, individualized contact with them. However, while GTAs have power in enacting curriculum, they have less power than instructors in designing curriculum. This (lack of) pedagogical partnership between GTAs and instructors can create tension. Pedagogical partnership is defined as "a collaborative, reciprocal process through which all participants have the opportunity to contribute equally, although not necessarily in the same ways, to curricular or pedagogical conceptualization, decision making, implementation, investigation, or analysis" (Cook-Sather *et al.*, 2014, pp. 6–7). Typically, pedagogical partnership is conceptualized between students and teachers (Cook-Sather *et al.*, 2021, 2014). However, we posit that pedagogical partnership may be useful to extend between GTAs and instructional teams, due to the power dynamics navigated by GTAs in their many contradictory and intersecting roles. Therefore, GTAs navigate this position in unique ways within their sections. Sparrow's and (Blue) Jay's cases both expose the tension and resolution between learning objectives (*i.e.,* objectives set by the instructional team for students) and teaching objectives (*i.e.,* objectives set by the GTAs for themselves and their students) through how their framing influences their enactment.

We (IZ and GVS) designed a scaffolded, cooperative-learning case-comparison activity based on chemistry education literature (Caspari and Graulich, 2019; Graulich and Caspari, 2021; Haas et al. 2024; Watts *et al.*, 2021), and the instructional team defined the learning objective as supporting students' multivariate reasoning. Our results demonstrated that both Sparrow and Jay attended to students' answers, interpreted students' knowledge, and responded with scaffolding questions. Our findings support Geragosian *et al.*'s (2024) findings, where they established the importance of teacher noticing to analyse what questions chemistry GTAs ask and how they are asked in the classroom. Moreover, their teacher noticing supported the course's learning objective. However, Sparrow and Jay shaped students' answers, asking more questions and eliciting more answers. While this shaping supported the course's learning objective, it also supported their teaching objectives. Because of the context of the course and Sparrow's learning experiences (*i.e.,* framing), they wanted to create a relaxing learning environment. Similarly, because of Jay's research and learning experiences (*i.e.,* framing), they wanted to motivate students' skill development and transfer. Respectively, their framing encouraged and influenced their shaping, and their shaping balanced the course's learning objective and teaching objective.

Shaping requires an "inquiry stance" (van Es and Sherin, 2021), yet GTAs may not share this inquiry stance. Some GTAs hold extrinsic motivations for teaching. Even if other GTAs do share this inquiry stance, some struggle to enact it, due to barriers, such as time commitments, amount of teaching experience, amount of professional development, conceptions of teaching, *etc*.. Our results, as exemplified through Sparrow's and Jay's enactment of the case-comparison activity, highlight that instructional teams can mediate these tensions. Instructional teams can support GTAs with teaching practices that satisfy both objectives, as this instructional team provided support around enacting a jigsaw activity and probing questions.

Moreover, the composite case highlights the change from implementation to enactment in a classroom. During this change, we observed instances where our participants' enactment was supported by pedagogical dialogue. For example, Jay's gallery walk was a proposed response to student engagement, but it was not an impromptu response until the researchers encouraged that "*It's not too late.*" We interpreted this participant-researcher interaction as a GTA-GTA interaction, considering our positionality and established rapport. However, we acknowledge that others (*e.g.,* the faculty instructor, participant, or the students) may have interpreted this participant-researcher interaction as a designer-enactor interaction. This interaction may be a source of evidence to support the idea of having a community to dialogue about pedagogical strategies can be important to GTAs in enacting activities in alignment with their teaching objectives. For another example, Sparrow's peer-GTAs influenced their planned responses. Sparrow's half of the composite case suggests the importance of teacher learning as a community and social process, instead of an isolated practice. Pedagogical communities of practice (teacher-learning communities, pedagogical learning communities, faculty learning communities, *etc.*) are important professional learning strategies that can support sustainable pedagogical innovation and change (Tinnell *et al.*, 2019; Vescio *et al.*, 2008; Voelkel and Chrispeels, 2017). Pedagogical communities of practice may lend to pedagogical partnership efforts within instructional teams, with GTAs engaged in reflective learning together. For example, designers and faculty instructors could provide pedagogical dialogue and support GTA autonomy in modifying classroom activities in alignment with evidence-based teaching practices.

Furthermore, throughout Jay's and Sparrow's cases, we highlight the teacher noticing cycles where GTAs enacted a reformed instructional activity informed by their student-centred teaching objectives, relevancy and confidence, respectively. These results highlight a common challenge of GTAs in negotiating or conceptualizing a teacher identity despite engaging in teaching practices (Robertson and Yazan, 2022; Zotos *et al.*, 2020, p. 20). For example, Jay's gallery walk successfully encouraged the student participation in the whole-group setting. This teacher strategy came from Jay's knowledge as a STEM education researcher, emphasizing the way their framing influenced their teacher noticing. However, while successfully teaching, Jay felt isolated from the identity of teacher. Therefore, Jay's half of the composite case suggests a need to validate, empower, and provide support to GTAs in enacting teaching objectives (Zotos *et al.*, 2020). This composite vignette showcases experiences where enacting this activity created moments of tension for themselves as teachers. GTAs have reported viewing themselves as "managers" or "babysitters" and feeling "underprepared," "overwhelmed," "isolated," and "frustrated" (Sandi-Urena et al., 2011; Sandi-Urena and Gatlin, 2013; Zotos et al., 2020). Despite observing throughout the results clear instances of teaching (*i.e.,* posing advancing and assessing questions, scaffolding larger-scale questions, supporting students' affective experiences, *etc.*), the GTA cases reported feeling disconnected from autonomy and teacher identity in their classrooms, likely informed by the disciplinary context, positionality, and power dynamics.

Within our findings, there is a specific focus on the power dynamics between the instructional team (faculty and instructional designers) and the GTAs. In a variety of literature on GTAs, both undergraduate students (Golish, 1999) and GTAs themselves (Shultz *et al.*, 2019) viewed GTAs as less powerful and agentic than faculty members. GTAs specifically expressed the most constraints when discussing the institution (Shultz *et al.*, 2019), highlighting the connection between the institutional (curricular) power GTAs hold and struggles in negotiating their teacher identity (Zotos *et al.*, 2020). The literature affirms our findings, that GTAs, especially in chemistry laboratories, did not view themselves as instructors or teachers (Sandi-Urena *et al.*, 2011; Sandi-Urena and Gatlin, 2013; Zotos *et al.*, 2020). The difficulties in identity formation, as seen through Sparrow and Jay's composite case, may be linked to a lack of autonomy and supportive social environments (Buchanan, 2015). The literature of faculty's experiences of implementing and enacting innovative STEM pedagogies highlights the importance of faculty self-determination, autonomy, and power regarding "a sense of choice around course content and instruction" (Couch *et al.*, 2023). Findings have shown that "autonomy was the strongest predictor of intrinsic motivation… [and] conversely, a lack of autonomy has been identified… as a barrier to their engagement in teaching reform" (Couch *et al.*, 2023, p. 2). Considering the literature on faculty experience with autonomy and power dynamics in pedagogical reform, we posit that extending this same understanding may elucidate the challenges that GTAs experience navigating limited curricular power but more extensive classroom management power in their new role.

Conclusion and Implications

In this study, we explored how chemistry graduate teaching assistants (GTAs) enacted a(n) (scaffolded cooperative-learning case-comparison) activity through a case study, focusing on the two cases of Sparrow and (Blue) Jay. Using the teacher noticing framework to guide data collection and analysis, we found that chemistry GTAs attended to students' questions, interpreted students' knowledge, and responded with scaffolded questions. Sparrow and Jay both shaped student interactions through inquiry, engaging in a student-centred pedagogy, satisfying the learning objective of the course. Further, we found that Sparrow and Jay's teaching strategy of questioning satisfied their teaching objectives, informed by their framing.

There has been minimal research or acknowledgement of GTAs' autonomy and self-determination at the classroom, curricular, or institutional levels, especially within chemistry education research. This study contributes to this growing area of teaching, and we encourage more research on and attention to GTAs' teaching and autonomy for teaching. Given Sparrow's and Jay's framing, we emphasize how GTAs have multifaceted teaching and learning experiences, teacher identities, and teaching objectives, which inform how they enact in-class activities and notice in the classroom. Therefore, instructors and researchers must consider GTAs' framing when designing curricula. Typically, studies suggest professional development on the departmental level (Geragosian *et al.*, 2024; Luft *et al.*, 2004; Wan *et al.*, 2020). We agree, but we also acknowledge the limitations in implementing those suggestions (*e.g.,* departmental pedagogical commitments or funding). Traditional professional development does not require the transformative act of lead instructors sharing or shifting power dynamics to GTAs; however, we suggest that shifts in autonomy may empower GTAs.

Rather than one-time pedagogical professional development, we posit shorter, smaller-scale opportunities to discuss pedagogical strategies (*e.g.*, in weekly staff meetings). Furthermore, we suggest consistent professional development on the instructional team level with multiple variations of pedagogical partnership: transparency in communicating learning objectives as well as instructional materials and strategies; collaboration in developing learning objectives as well as instructional materials and strategies; and community in teacher learning. Transparency in communicating learning objectives would invite GTAs to *understand* and *navigate* the instructional materials provided to them with appropriate teaching strategies. For example, in this staff meeting, the instructional team outlined the learning objectives for the activity and provided teaching strategies that aligned with the learning goals for students. Possibilities for formative assessment could also be outlined. Collaboration in developing learning objectives would invite GTAs to *share* their teaching objectives and *co-create* with the instructional team. For example, GTAs might engage in reflective activities about their goals for students and instructors may support these goals by co-creating pathways to enact evidence-based teaching strategies that can balance tensions and satisfy both learning and teaching objectives (*i.e.,* scaffolding questions). Community in teacher learning would intentionally *develop* structured venues for GTAs to learn together and *engage* in dialogue with other GTAs and instructions about teaching strategies to mediate tensions. For example, instructors can create structures for formal and informal mentorship and GTA-GTA dialogue about teaching struggles, strategies, and ideas. GTAs could synthesize these reflections, and the instructors could pass them down to the next semester's instructional team. We acknowledge that each of these recommendations may be done independently or in tandem, with some strategies requiring more sharing of power, more time, and more structure. Further, we encourage chemistry education researchers to partner with and engage in research with instructional teams who implement these changes to power dynamics and collaborate through pedagogical partnership.

Appendices

Appendix 1: Case Comparison 1 in the Case-Comparison Activity

GTAs divided students into Groups A or Groups B, small groups with four students. Here, students examined one of the two reactions, where Group As examined Reaction A, Group Bs examined Reaction B, and both groups answered Questions 1 – 4 in their laboratory notebooks. Questions 1 – 4 guided the groups' reasoning. Next, GTAs divided students into Group Cs, small groups with two Group A students and two Group B students. Here, students compared reactions and answered another Question 5 in their laboratory notebooks. Question 5 required the groups' reasoning. Then, GTAs transitioned students from their small-group discussions to a whole-group discussion. This sequence repeated for Case Comparisons 2 and 3. Within a week, students submitted their laboratory notebooks, and GTAs assigned them completion-based grades.

Your GSI will divide you into a group with 3-4 students. (This is **Group A**.) Work together to answer the following questions about Reaction W.

W

Figure 7 Reaction W

1. What structural features differ between the reactants and products? Structural features could include electrons, charges, atoms, functional groups, bonds, *ect*.
2. What chemical and physical properties do the structural features from Question 1 have? Properties could include electronegativity, size, steric effects, resonance effects, induction effects, *etc.*
3. What changes occur from reactants and products? Specify *what* structural features are changing and *how* they are changing. Changes could include forming a charge, breaking a bond, making a bond, *etc*.
4. Why do the changes occur? Explain as precisely as possible *why* the properties described in Question 2 cause the changes in Question 3.

Your GSI will sort you into another group. (Because you are from Group A, your group should include students from Group B. This is **Group C**.) Work together to answer the following question about Reactions W and X. Be prepared to discuss with the class!

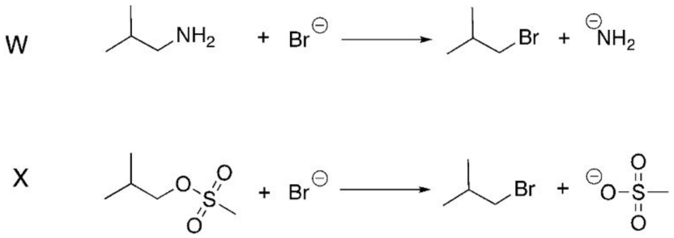

Figure 8 Reactions W and X

5. Which reaction occurs faster? Make a prediction. Your prediction should include a claim, evidence, and a warrant. The evidence should include a comparison between the structural features and their properties from Reaction W and those from Reaction X.
6. On your own, in your lab notebook pages, describe an “ah-ha” motivating moment or an “uh-oh” challenging moment. What did you learn about (ah-ha moment), or what are you still wondering about (uh-oh moment)?

Appendix 2: The Case-Comparison Rubric

Students completed the laboratory write-up. The laboratory write-up asked, “Which reaction occurs faster?” or Q5 for Case Comparison 3. Students revisited their laboratory notebooks and elaborated their answers, incorporating and / or discarding information from peers and their GTA. Within a week, students submitted their laboratory write-ups, and GTAs assigned them rubric-based grades.

Table 3 The Case-Comparison Rubric

Criteria	Full Credit	Partial Credit	Minimal Credit	Points
Claim	The student included a descriptive claim that matched the goal of case comparison. (3)	The student included a claim, but it was incomplete or did not match the case comparison. (1-2)	The student did not include a claim. (0)	__ / 3
Evidence	The student included multiple pieces of evidence that directly supported the claim. The response could have included 1-2 pieces of evidence that were inaccurate. (5-6)	The student included multiple pieces of evidence that directly supported the claim. The response could have included 3-4 pieces of evidence that were inaccurate. (3-4)	The student included some pieces of evidence that directly supported their claim. However, multiple issues were present, such as including evidence that was contradictory or more than 4 pieces of evidence that were inaccurate. (1-2)	__ / 6
Reasoning	The student included multiple sentences that provided explanations for why they thought the evidence supported the claim. The response could have included 1-2 explanations that were inaccurate. (5-6).	The student included multiple sentences that provided explanations for why they thought the evidence supported the claim. The response could have included 3-4 explanations that were inaccurate. (3-4)	The student included some sentences that provided explanations for why they thought the evidence supported the claim. However, multiple issues were present, such as including more than 4 explanations that were inaccurate. (1-2)	__ / 6

Author Contributions

All authors contributed. IZ and DBH. *equally* contributed to the conceptualization, the methods (*i.e.,* interview protocol design, data collection, data analysis, and results), and the writing of this manuscript. MJS contributed to the methods (*i.e.,* data analysis) and the writing of this manuscript. IZ and GVS. contributed to the design and the implementation of the assignment. GVS provided extensive, valuable feedback and contributed to the revising of this manuscript. All authors read and approved this manuscript.

Conflicts of Interest

There are no conflicts to declare.

Acknowledgments

We wish to thank the graduate students for participating in our study. Additionally, we wish to thank group members Danielle N. Maxwell, Rebecca C. Fantone, and Solaire A. Finkenstaedt-Quinn for providing feedback on our manuscript. This study was funded by NSF GRFP number 000884418.

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A Case Study on Graduate Teaching Assistants' Teacher Noticing When Enacting a Case-Comparison Activity in Organic Chemistry

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No shareable primary research results, software or code have been included and no new shareable data were generated or analysed as part of this study.