

Investigating Teacher–Teacher Feedback: Uncovering Useful Socio-pedagogical Norms for Reform-Based Chemistry Instruction

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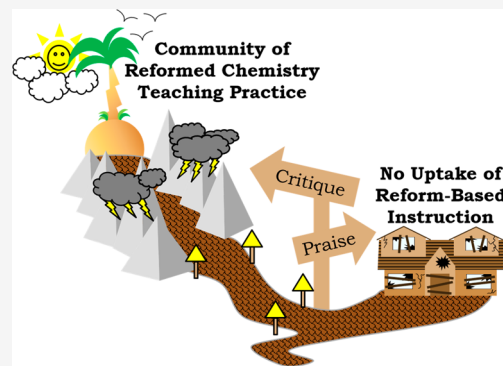
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ABSTRACT: Teacher–teacher feedback is an important feature of professional learning. However, deeply ingrained socio-pedagogical norms may affect both the nature and content of feedback, constraining its effectiveness. Prior studies have reported that avoiding critique and providing excessively generic information can hinder pedagogical inquiry and adoption of reform-based instruction. To better understand the nuances of socio-pedagogical norms for chemistry-specific settings, we investigate the conversational functions and the ways in which teacher–teacher feedback addresses macroscopic, symbolic, and particulate levels of representation within lessons they experienced as students. We deductively coded 16 instances of feedback provided by eight VisChem Institute-2 teacher participants. Results from the first phase of analyses indicate that teacher–teacher feedback largely comprised of praise with few instances of critique. The second phase of analyses shows that teacher–teacher feedback most frequently referenced the particulate level. Synthesizing the results, we find that more chemistry-specific topics were referenced in conversational functions that prepare teachers for pedagogical change. Our findings suggest foregrounding the particulate level may support teachers' critical engagement with each other. We thus recommend that teacher educators and professional developers base mutual engagement, shared repertoire, and the joint enterprise on the particulate level when constructing a community of reformed chemistry teaching practice. We also provide insights on how our findings can be adapted for chemistry graduate teaching assistants and raise new questions about investigating spiraling, dialogic forms of feedback.

KEYWORDS: High School/Introductory Chemistry, Chemistry Education Research, Collaborative/Cooperative Learning, Professional Development



INTRODUCTION

The National Research Council¹ has provided key assumptions that guide current understandings of chemistry teaching and learning. Our discipline is “not just a body of knowledge that reflects current understanding of the world” but also “a set of practices used to establish, extend, and refine that knowledge” (p 27). Recommended by the *Next Generation Science Standards*,² these practices include using models and constructing explanations that are crucial for chemistry conceptual understanding.³ At the high school level, teachers indubitably function as the linchpin for facilitating student achievement concurrent with reform-based initiatives. Understanding the relationality of teachers, their beliefs and values, the learning of pedagogy and chemistry, and the curriculum as well as how it is enacted is essential for advancing the instructor's role as an agent of change.^{4–7}

Unfortunately, high school teachers are often treated as objects of reform rather than co-constructors insofar as they are the last ones to hear, know, or voice their ideas.⁸ High-quality professional development (PD) is paramount, wherein teachers collaborate, raise issues, and navigate uncertainties associated

with their pedagogical practices.⁹ We contend that setting PD norms (i.e., how and what is prioritized throughout teacher talk) around mutual engagement, shared repertoire, and a joint enterprise via a community of practice¹⁰ is a prerequisite for teachers' future success. Currently, the nuances of these norms within a chemistry PD context are underexplored. In our ongoing mission to engender reform-based chemistry instruction at both the high school and undergraduate levels, we recognize an urgent need to identify promising PD design principles. We turn our attention to the norms specifically governing teacher–teacher feedback and its novelty and relevance for chemistry education research.

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■ BACKGROUND

Many studies have consistently reported that productive PD includes lively, substantive, and critical discussion among participants.^{11–13} A cornerstone of this type of teacher engagement is peer feedback and its role as a channel for communication. However, the benefits of teacher–teacher feedback are stymied by other deeply ingrained discursive norms that constrain the nature and content of dialogue among teachers.¹⁴ Specifically, the conventions that surround teacher–teacher feedback can act as a bottleneck that limits professional learning.

Our review of the literature has identified two ongoing and interconnected themes that impede meaningful teacher–teacher feedback. First, teachers may refrain from expressing disagreement or critique. The social pressure to remain professional and collegial discourages teachers from challenging each other's ideas, thereby preventing moments to identify instructional alternatives, debate on various possibilities, and generate new pedagogical practices.^{15,16} When restricted, the nature of teacher–teacher interactions remains superficial and characterized by messages of praise and validation with less attention to inquiry.^{17,18} How teachers engage in feedback with each other is a crucial factor that mediates considerations for transforming their chemistry pedagogies.

Second, the content of feedback among teachers has been excessively descriptive¹⁹ and summative instead of formative.²⁰ Teachers typically overemphasize classroom management throughout their suggestions to each other.²¹ Carless et al.²² recently noted that feedback being too generic is also problematic because effective implementation often fails when it is not focused on discipline-specific customs and procedures. For example, feedback in engineering instruction is inherently different than that associated with teaching medicine or art.²³ We recognize that the effectiveness of teacher–teacher feedback is not only contingent upon how they engage with each other but also on *what* teachers deliberate and value.

While the dearth of meaningful teacher–teacher feedback obstructs instructional improvement,²⁴ the fuzziness around what is “meaningful” in chemistry and the routes to breach surface-level discourse (i.e., gratuitous pleasantries) also warrant more specification.²⁵ The purpose of our study is to better understand the nuances of teacher–teacher feedback governed by discursive patterns and contextualized in the three levels of chemistry representation: macroscopic, symbolic, and particulate.²⁶ Because chemistry education researchers and practitioners frequently endorse learners' fluidly connecting between representational levels,^{27–29} clarifying the nature and content of teacher–teacher feedback on chemistry instruction can open new doors for enriching discipline-specific professional learning.^{30,31} This study's purpose is to provide teacher–teacher feedback guidelines that are specific, accessible, and practical.³² Our intent is to support teachers so that they can navigate the countless assortment of feedback practices³³ and select those that are productively affiliated with a community of reformed chemistry teaching practice.

■ THEORETICAL FRAMEWORK

We draw upon multiple foundational assumptions regarding teacher learning via peer feedback. First, we leverage Dick et al.'s idea of *socio-pedagogical norms*,³⁴ defined as the “participation patterns that become established and subsequently enacted when teachers are talking with their colleagues about

instruction” (p 297). Like other researchers who investigate teacher discourse,³⁵ we foreground the importance of context dependency. Unlike norms that are emergent from and reinforced by classroom practices, teacher–student interactions, and students' developing discipline-specific ideas,³⁶ socio-pedagogical norms focus on teacher talk in professional learning settings. Thus, uncovering the customs, expectations, and ideas that teachers exhibit when talking to their peers provides important insights on how PD conversations can be shaped by socio-pedagogical norms to further promote high-quality PD and uptake of reform-based instruction.

Scholars have historically recommended that professional developers prioritize problems teachers face in their daily work, students' content ideas, and opportunities to scrutinize and enact pedagogies.^{37–41} From our literature review, teacher–teacher feedback is portrayed as a cross-cutting practice throughout all components of high-quality PD. For our study, we focus on the socio-pedagogical norms that undergird teacher–teacher feedback. Feedback is defined as providing information in response to aspects of one's performance or understanding.⁴² Receiving feedback can reduce discrepancies with respect to a desired goal.^{43,44} Specifically, Carless⁴⁵ identified that “the most powerful feedback often has a critical longer-term dimension in that it provokes thinking, reflection, and then considered action” (p 709).

Identifying socio-pedagogical norms requires robust theories that articulate the nature (i.e., the “how”) and content (i.e., the “what”) of teacher–teacher feedback. In terms of the “how”, we synthesize features of critical collegiality and Critical Friends Groups given their established role in facilitating teacher professional learning. Lord⁴⁶ described critical collegiality as teachers' asking questions about and reflection on their practice. Teachers are incentivized to challenge implicit assumptions and inspect taken-for-granted pedagogies, ushering in new ideas and changes to enacted practice.^{47,48} Similarly, the “Critical” in Critical Friends Groups is actually unrelated to the critique of work but rather refers to how teachers are evaluative of and themselves vital for their learning.⁴⁹ The social protocols of Critical Friends Groups aim to problematize existing ideas and interrogate implications of teaching via robust and pedagogically rich conversations.^{50,51} Based on these readings, we agree that critique is a fundamental component for productive teacher–teacher feedback. Socio-pedagogical norms should encourage teachers to reflect, think past the status quo, and propose different pedagogies without the filtering effect of being overly complementary.

Nevertheless, because teaching is deeply personal,⁵² we acknowledge that change toward reform-based practice is profoundly affective.⁵³ Perhaps the need to safeguard one's own emotions and the associated sympathy are why teacher–teacher feedback tends to be more courteous in nature. Nevertheless, when orchestrated with appropriate socio-pedagogical norms, professional critiques can spur a teacher to recognize previously unnoticed problems. Feedback should assist teachers in expanding their views so the epistemological differences between traditional and reform-based teaching can be more easily discerned.⁵⁴ Teacher–teacher feedback should therefore instigate a sense of pedagogical discontentment,⁵⁵ giving rise to pedagogical conceptual change⁷ and even a reshaping of one's core teaching identity.⁵⁶

Thompson and Zeuli⁵⁷ furthermore described coinciding requirements for teachers' transformative rethinking. These include initially generating sufficient cognitive dissonance

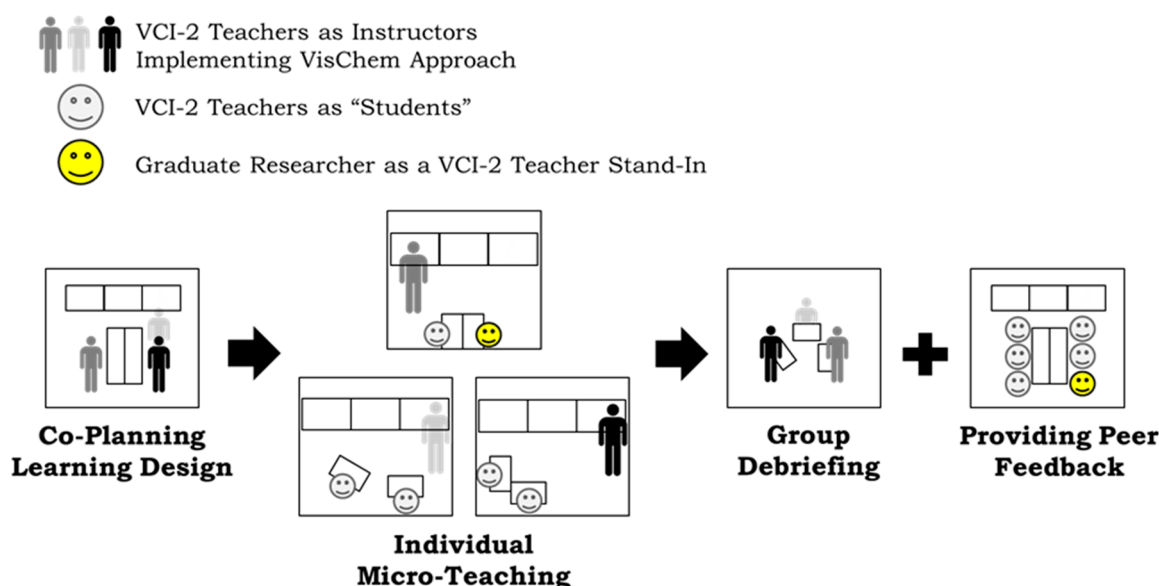


Figure 1. Diagram of VCI-2 activities. One graduate researcher acted as a VCI-2 teacher to ensure that there was an equal number of teachers per group. Group arrangement, PD programming for teacher–teacher feedback, and information regarding the graduate researcher are described in [Data Collection](#).

between teachers’ beliefs and practices with various components of teaching such as students’ ideas, discipline-specific content, and pedagogical principles. The authors urged teachers to address and resolve said dissonance via “crystallization, externalization, **criticism**, and revisions of their thinking” (p 356, emphasis added). These insights underscore the need for teacher–teacher feedback to be strategically critical as well. Socio-pedagogical norms that merely assist teachers in surmounting niceties in their feedback are insufficient.

As a result, we posit that the content (i.e., the “what”) of teacher–teacher feedback must also be finely tuned to chemistry-specific ideas about teaching and learning. In other words, our theoretical lens must simultaneously consider the extent to which teacher–teacher feedback is critical and the ways its content specifically interfaces with chemistry. We thus use Johnstone’s triangle²⁶ and its representational levels as the final analytical component to more deeply understand socio-pedagogical norms of chemistry.

Johnstone’s triangle consists of three vertices: the macroscopic (e.g., laboratory experiment), the symbolic (e.g., written formulas, equations), and the submicroscopic or particulate (e.g., atoms, ions, molecules). Promoting students’ connections between representational levels enables modeling practices, understanding of complex relationships, and visualization of abstract chemical phenomena.⁵⁸ Johnstone’s triangle is a foundational component in chemistry education research, as evidenced by its ubiquity in student interventions, theories of chemistry learning, and professional development design.^{28,59,60} In addition, our attention to the particulate level is warranted due to its role as the bedrock for chemistry conceptual understanding⁶¹ and its centrality to our PD program and its modeled pedagogy.⁶² By evaluating both the nature and content of teacher–teacher feedback, we aim to propose new avenues of catalyzing pedagogical inquiry such that educators can agentively meld reform-based initiatives into their extant practices.⁶³ We ask the following research questions:

RQ1: What are the nature and chemistry content of teacher–teacher feedback in immersive professional development that center microteaching?

RQ2: What insights about socio-pedagogical norms are afforded by juxtaposing the nature and chemistry content of teacher–teacher feedback simultaneously?

SETTING

The VisChem Institute-2 (VCI-2) is an intensive, in-person PD program for in-service high school chemistry teachers sampled from across the United States. Taking place in July 2022, the VCI-2 comprised of two and a half days with a total of 28 PD hours (with additional time for completing prework and asynchronous work). [Figure 1](#) shows VCI-2 activities, which include participants’ coplanning a learning design (a student-centered lesson plan with the VisChem Approach as the focal point), microteaching, and debriefing in small groups. Because feedback is more effective when the source of information is perceived to be credible, knowledgeable, and lower or equal in status with respect to the recipient,⁶⁴ there were multiple occasions throughout the VCI-2 when participants provided feedback to each other (both formally and informally). More information regarding VCI-2 programming is detailed in a previous report from the project.³

The VCI-2’s primary objective was to improve classroom readiness for implementing the VisChem Approach, the pedagogy that we as facilitators modeled for participants in the previous institute. Inspired by the cognitive learning model, the VisChem Approach is a series of instructional moves that leverages dynamic, molecular-level animations and storyboards (i.e., drawings with written captions).⁶² This pedagogy can be distilled into five instructor practices: (1) showcase a macroscopic phenomenon to prime the learner’s perception filter for incoming visual and auditory stimuli; (2) elicit students’ initial ideas by having them create a pre-animation viewing storyboard; (3) coordinate engagement with a VisChem animation and simultaneously reduce the potential for cognitive overload; (4) prompt student discussion, reflection, and creation of a post-

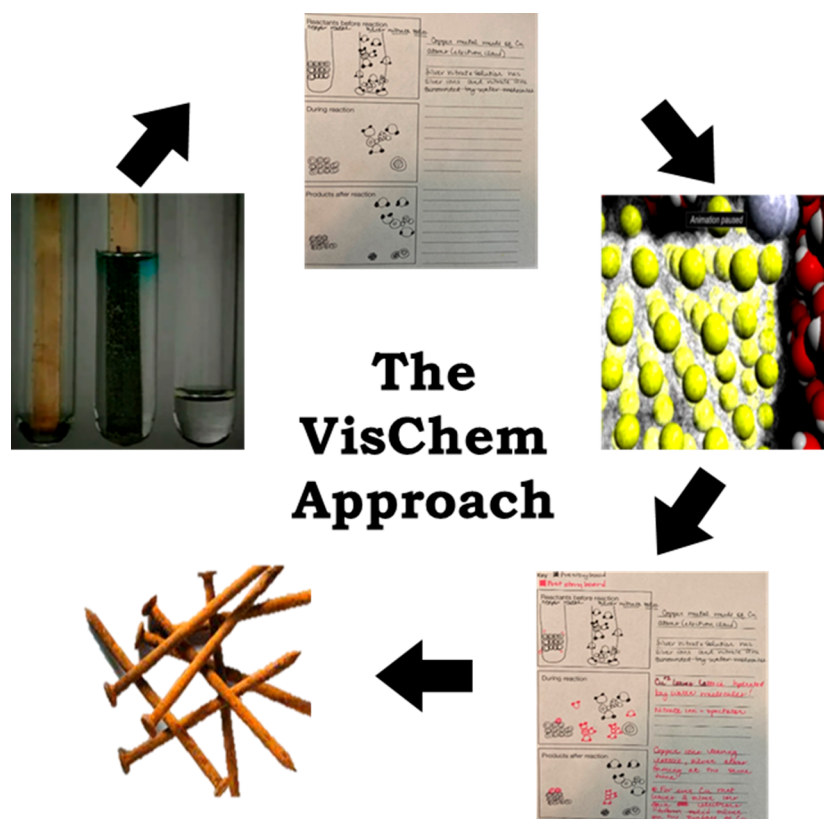


Figure 2. Five steps of the VisChem Approach, contextualized in the redox of solid copper with aqueous silver nitrate. A pre-animation viewing storyboard (with no pink edits), a screenshot of a VisChem animation, and a post-animation viewing storyboard (with pink edits) are shown.

animation viewing storyboard; and (5) enable opportunities for students to link new ideas to their prior knowledge (Figure 2). By design, the VisChem Approach incorporates key components of the *Next Generation Science Standards*, such as an emphasis on chemical explanations and particulate-level models.^{2,65}

Unlike prior iterations of the VisChem Institute (VCI) that had new cohorts of teachers each year and focused on the learning of chemistry and pedagogy,⁶⁰ the VCI-2 reinvited teachers to extend and build upon what they had already learned at previous VCIs. The sampling protocol we used differed from the 2020 and 2021 VCIs (the latter detailed in a forthcoming article). We purposely chose VCI-2 teachers based on two criteria. During March 2022, we sent a survey asking teachers from the 2020 and 2021 cohorts whether they had collected student data and how interested they were in supplementary PD. The first question was rationalized by our overarching mission to broaden student impact by choosing teachers who were concurrently enacting the VisChem Approach in their classrooms. The second question emerged from our desire for teachers to develop face-to-face rapport and strengthen their community of practice (the 2020 and 2021 VCIs were remotely delivered due to the pandemic). We sent 22 emails via Qualtrics and received nine responses who met our qualifications. Although all nine teachers were invited, only eight teachers (five and three from the 2020 and 2021 cohorts, respectively) participated in the VCI-2 (see Table 1).

METHODS

Data Collection

Three groups, each comprising three teachers (one group had two teachers and a graduate researcher), were assigned one of

Table 1. VCI-2 Teacher Participants Identified by Their Code Numbers

2020 Cohort	2021 Cohort
104	206
106	209
109	210
110	
115	

three chemistry topics at the VCI-2: phase changes of water, dissolution of sodium chloride, and redox of solid copper with aqueous silver nitrate. Before the VCI-2, teachers were instructed to prepare lesson materials for their assigned topic. Once they had arrived, teachers worked in small groups to synthesize a coplanned learning design. Our primary requirements were that teachers must incorporate the VisChem Approach, the teaching duration must be 90 minutes in total (split into two 45 minute microteaching sessions with a break in between), and the lesson plan must be something teachers could realistically implement in their classrooms in the future. Otherwise, teachers had full discretion concerning the extent to which they wished to incorporate the macroscopic, symbolic, and particulate levels of Johnstone's triangle. The VCI-2 teachers then individually taught their assigned chemistry topic with two other teachers (from other groups) who acted as students (see Figure 1).

Once both microteaching sessions had concluded, all teachers who had previously acted as students sat in a room together (see Figure 1). The VCI-2 did not use Critical Friends Group social protocols or explicitly establish socio-pedagogical norms to steer teacher–teacher feedback. Instead, VCI-2 teachers were

prescribed 30 min. to silently and individually write feedback in the form of perceived strengths, improvements, and insights with respect to their peers' microteaching.⁶⁶ PD facilitators elaborated on the instructions by directing teachers to be as specific as possible with their feedback. Teachers were also reminded to include any relevant experiences and prospective thoughts on increasing classroom readiness for VisChem Approach implementation. We note that during the VCI-2, there were no programmed activities in which teachers discussed their experiences as "students" among themselves or with those who had previously enacted the VisChem Approach prior to, during, or after the feedback writing. Furthermore, although groups of teachers immediately had access to their received feedback, we are unsure whether teachers had reviewed their peers' ideas prior to the next round of microteaching due to the VCI-2's intensity. Thus, how receiving feedback influences teachers' subsequent provision of feedback is beyond the scope of this study.

Attending to how VCI-2 teachers responded to the microteaching via feedback enabled the research team to detect emergent socio-pedagogical norms. For the purposes of this study, feedback from the graduate researcher to the VCI-2 teachers was not considered as part of the data corpus. Our rationale was that the graduate researcher's experiences were not commensurate with those of participating teachers and thus may not as sensitively resonate with socio-pedagogical norms when providing feedback. However, feedback provided from the VCI-2 teachers to the graduate researcher was analyzed.

This sequence was repeated so that all VCI-2 teachers experienced microteaching, acting as students, and providing feedback. By the end of the VCI-2, the eight teacher participants had each given feedback on their peers' implementation of the VisChem Approach twice, resulting in 16 instances of teacher–teacher feedback. All teacher artifacts were submitted via Google Drive. The protocols for collecting, analyzing, and reporting data were reviewed and approved by the PD-hosting university's institutional review board.

Data Analysis

Our analyses of the teacher–teacher feedback were conducted in two phases. First, our coding was primarily deductive. We used a previously established coding scheme⁶⁷ to characterize the conversational functions (CFs) of segments within teachers' feedback. The term "conversational function" encompasses both the teacher's stance⁶⁸ and the type of message conveyed through teacher discourse.⁹ For our study, the coding of CFs aimed to categorize the nature of teacher–teacher feedback. Table 2 shows 13 initial CF codes with summarized definitions.

Our systematic coding scrutinized the conversational function of teachers' feedback meticulously. Each coded segment of a teacher's feedback spanned one or two sentences. All coded segments were similar in length, enabling our comparisons of frequency among each code category. After cycles of both deductive and inductive coding, disagreements arose when segments were coded as separate excerpts versus in context. As such, codes were revised to capture interpretations in context (i.e., holistically leveraging preceding and proceeding sentences). Weekly discussions around code refinement, reapplication, and considerations for maximizing saturation⁶⁹ (i.e., the extent to which the CF codes adequately account for all salient patterns within the data) led to our tentative coding scheme. Emergent discrepancies throughout the coding process were resolved, resulting in a mutually agreed upon codebook that consisted of

Table 2. Initial Conversational Function Coding Scheme

Function	Definition
<i>Greet</i>	Introduce comment via salutation.
<i>Describe</i>	Narrate events from prior post.
<i>Imagine</i>	Express curiosity about what could have happened.
<i>Interpret</i>	Provide and/or extend a new lens.
<i>Praise</i>	Provide a positive reaction.
<i>Connect Experiences</i>	Share experience.
<i>Validate</i>	Affirm via agreement or appreciation.
<i>Critique</i>	Disagree with prior post.
<i>Share</i>	Recall from one's own teaching experience.
<i>Suggest</i>	Provide an idea for someone to try out in the future.
<i>Clarify</i>	Ask for extra detail and/or explanation.
<i>Take Up</i>	Indicate feature one plans to later incorporate.
<i>Other</i>	Comment is incompatible with above codes.

seven codes. Table 3 shows our finalized CF scheme with codes, their adjusted definitions, and corresponding examples. The "{" symbols indicate a preceding excerpt of a teacher's feedback to provide readers additional context.

The second phase of our primarily deductive analyses identified the content of teachers' feedback. We incorporated Johnstone's triangle (JT)²⁶ as an additional analytical lens to differentiate teacher feedback that was either *Non-Chemistry* or *Chemistry-Specific*. Of the CF-coded segments that were *Chemistry-Specific*, the teacher–teacher feedback was later categorized based on its inclusion of macroscopic, symbolic, or particulate information. Teachers' feedback that referenced the connection of multiple representational levels was also noted. After multiple cycles of JT coding, the negotiation of emergent disagreements bolstered the robustness of our codebook. Table 4 shows our finalized JT scheme with codes, definitions, and examples.

In summary, our analyses consisted of two phases in which we evaluated both the nature and content of teacher–teacher feedback. Figure 3 shows a flowchart of our coding procedure. Our analyses led to portions of teacher–teacher feedback whose nature was characterized by a conversational function. Afterward, the content of the teacher artifacts was categorized as *Non-Chemistry* and *Chemistry-Specific*, with the latter being further delineated by Johnstone's representational levels.

We adopt Lincoln and Guba's evaluative criteria⁷⁰ to ensure the trustworthiness of our findings. On credibility, the first and second author had independently coded 10% of the data once the codebooks for both phases had been finalized. We obtained inter-rater agreements of 85% and 97% for CF and JT coding, respectively. On transferability, our study is grounded in principles of teacher learning recommended by both seminal and current teacher education literature. We also used Geertz's notion of a thick description⁷¹ in our analyses of teacher feedback via Johnstone's triangle. Each coded segment was carefully analyzed to identify its potential relation to one or multiple level(s) of chemical representation. By capturing the richness of chemistry content throughout teachers' feedback, showcasing examples grounded in teachers' voices, and connecting the VCI-2 context to broader community of practice aims, we intended to increase our work's relevance for chemistry education researchers and practitioners at both the high school and undergraduate levels. On dependability, our finalized codes were deemed to thoroughly account for variations between and within the 16 instances of teachers' feedback.

Table 3. Finalized Conversational Function Coding Scheme

Function	Definition	VCI-2 Teacher Examples
<i>Describe</i>	Narrate events explicitly related to microteaching in a neutral tone (neither explicitly positive nor negative)	<i>You were sensitive to the amount of time students needed to complete assignments.</i>
<i>Elaborate</i>	Provide thoughts (unassociated with <i>Praise</i> or <i>Recollect</i>) on pedagogy or content that qualify its value and extend an occurrence or feature during the microteaching	<i>{I like the use of Post-its} for related work that you do not want to have permanently written on the page.</i>
<i>Praise</i>	State an explicitly positive sentiment or reaction toward a feature during the microteaching (e.g., like, appreciate, enjoy, or love) or use an explicitly positive qualifier (e.g., good, great, or excellent) about the microteaching	<i>Loved the final task of students "calling out" revisions to the storyboard in a different color.</i>
<i>Critique</i>	State an explicitly negative sentiment (e.g., dislike, felt frustrated, or felt lost) or reaction toward something that was done or omitted during the microteaching	<i>I did not feel the video of melting ice helped much with the understanding of what was happening (not on you as a teacher though).</i>
<i>Recollect</i>	Articulate something explicitly (via personal pronouns) about the speaker's own classroom or personal teaching experience	<i>I rarely make use of exit tickets (Post-its).</i>
<i>Suggest</i>	Provide, explicitly or implicitly (e.g., I think or I wonder), a prospective modification to the microteaching	<i>But then wondered if there is a way to revisit or summarize the thoughts from the students at the beginning of Day 2 as an icebreaker into the second half of the lesson.</i>
<i>Take Up</i>	Indicate something about the microteaching the speaker plans to incorporate into their future practice	<i>I can see incorporating this practice into my classroom.</i>

Table 4. Finalized Johnstone's Triangle Coding Scheme

Code	Definition	VCI-2 Teacher Examples
<i>Macroscopic</i>	Pertaining to observable chemistry phenomena (i.e., videos, laboratory experiments, or demonstrations)	<i>I enjoyed how you added a video to show phase change.</i>
<i>Symbolic</i>	Relating to formal signs used in chemistry to communicate information (i.e., written equations or graphs)	<i>The way you led us through the net ionic equation portion was helpful.</i>
<i>Particulate</i>	Referring, explicitly and directly, to unobservable and molecular-level phenomena (i.e., atoms, ions, molecules, etc.) from a descriptive and/or explanatory perspective	<i>I liked that you showed the animation multiple times as part of the lesson design.</i>
<i>Multiple Connections</i>	Addressing at least two parts of Johnstone's triangle with their aforementioned definitions	<i>Good video selection that shows the related graph simultaneously.</i>
<i>Non-Chemistry</i>	Not explicitly having to do with Johnstone's Triangle	<i>Pacing was good for students.</i>

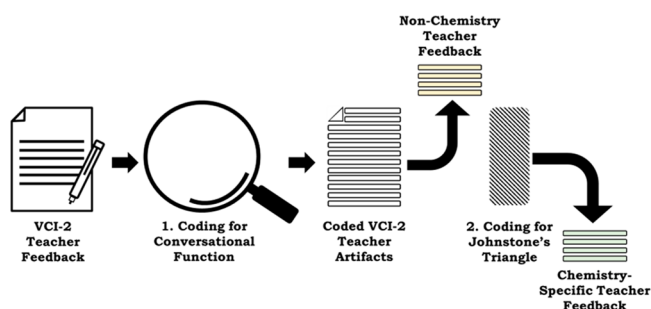


Figure 3. Flowchart of the coding scheme to investigate the nature and content of teacher–teacher feedback. The conversational function was first identified, and then coded teacher artifacts were subjected to an additional layer of analysis via Johnstone's triangle to maximize chemistry specificity.

Finally, on confirmability, we recognize our positionalities as both PD facilitators and researchers. The second author, having taught at the high school and college levels, brings a wealth of chemistry instructional experience. Both authors have in-depth understanding of VCI-2 design principles, intended learning outcomes, the VisChem Approach, and research-based instructional strategies for the learning of chemistry and pedagogy. In addition, the experiences analyzing various facets of the VCI helped both authors adopt emic perspectives essential for making sense of teacher participants' emergent and VCI-dependent discourse. We therefore purpose our subjectivities and expertise as a unique intersection among chemistry education, science education, and national reform efforts. The findings and discussions per each research question are intended to serve our chemistry instructors and learners at the high school and undergraduate levels.

RESULTS AND DISCUSSION

Research Question 1: What Are the Nature and Chemistry Content of Teacher–Teacher Feedback in Immersive Professional Development That Center Microteaching?

The first phase of analyses led to 269 CF-coded teacher artifacts. Figure 4 shows the frequencies of CF codes and their prevalence among VCI-2 teachers. Regarding the nature of teacher–teacher feedback, the greatest number was *Praise* (93) with the fewest being *Critique* (7). *Describe* (57), *Elaborate* (47), and *Suggest* (41) were also more frequent than other CF codes such as *Recollect* (14) and *Take Up* (10). On the prevalence of *Praise* and *Critique*, all eight VCI-2 teachers had incorporated *Praise*

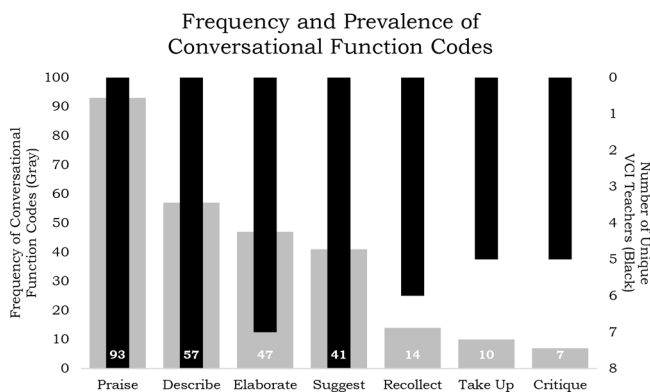


Figure 4. Graph of the frequencies of conversational function codes (shown in light gray) with the corresponding numbers of unique VCI-2 teachers (inverted and shown in black). Conversational function codes are organized in descending order, with *Praise* being the greatest and *Critique* being the least. Frequencies are listed at the bottom of each bar.

throughout their feedback, while only five had included at least one instance of *Critique*. Some examples include, “This was a great lesson!” (from Teacher 104 to 210) and “I appreciated your wealth of insight and experience you brought to the lesson” (from Teacher 210 to 109). These instances of *Praise* regarding others’ microteaching may benefit the recipient’s self-esteem or improve the relationship with the information source; however, they are neither problematizing nor generative. The nature of this feedback is less effective in incentivizing the recipient to notice how their pedagogy can be improved.

Our results of teacher–teacher feedback strongly adhering to positive sentiments resonate with the findings of other scholars.^{72,73} Despite following the Strengths, Improvements, and Insights (SII) format,⁶⁶ VCI-2 teachers wrote excerpts that overwhelmingly leaned more toward *Praise* than *Critique*. This discrepancy points to how politeness is a deeply ingrained socio-pedagogical norm. On one hand, perhaps there was not enough time for VCI-2 teachers to comfortably adopt a critical stance with others. On the other, VCI-2 programming and the feedback instructions may not have elicited teacher critique as we had intended. Prior studies have identified that teacher–teacher feedback avoids critique and tends toward positive sentiments due to lack of certain sentence stems (e.g., “I notice” or “I wonder”) and/or social protocols.^{50,67} Our findings build upon the notion that feedback is certainly a business of affects.^{74,75} Supported by other literature corroborating with politeness acting as a barrier, we speculate that the emotional response to feedback, if not productively managed, could interfere with the conveyed information and act as a hindrance to PD success.⁷⁶

The second phase of analyses separated the original 269 CF-coded teacher artifacts into two categories: *Non-Chemistry* (125) and *Chemistry-Specific* (144). Generally, we identified the *Non-Chemistry* feedback to be nondescriptive and/or peripherally related to chemistry conceptual understanding. For example, one teacher included a recommendation “to provide students with an additional framework for recording and analyzing their thoughts” (from Teacher 106 to 115). Even though 115 may have given students a “new way of recording and analyzing their thoughts”, what constitutes a thought and its semblance to chemistry ideas remain equivocal. Other *Non-Chemistry* feedback resembled generic compliments such as the statement, “It’s a great way to communicate students’ understanding and what they can improve upon” (from Teacher 209 to 115). Other instances include, “Pacing was good for students” (from Teacher 110 to GR) and “You are amazing” (from Teacher 209 to 110). We again note that 209’s positive feedback, while referencing student understanding, does not adequately address what students may understand (e.g., chemistry content, classroom norms, or logistics). We as researchers are left to surmise what teachers value when their feedback on their peers’ microteaching remains imprecise.

Of the *Chemistry-Specific* portion, Figure 5 shows the frequency of each representational level (*Particulate*, *Macroscopic*, *Multiple Connections*, and *Symbolic*) and its prevalence among VCI-2 teachers who had incorporated said level at least once throughout their feedback. To facilitate sensemaking of our findings, we remind readers that the content of VCI-2 teacher feedback was contingent on what VCI-2 teachers themselves prioritized. Even if the enacted microteaching and lesson plans had included various levels of representation, the content of the feedback (i.e., what features were explicitly about chemistry) was at the discretion of the individual teacher.

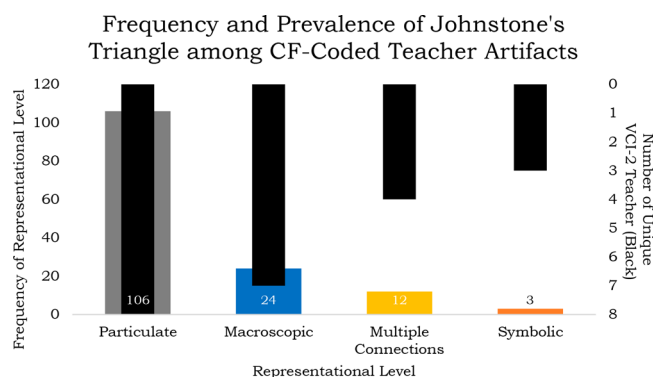


Figure 5. Graph of the frequencies of Johnstone’s triangle codes with the corresponding numbers of unique VCI-2 teachers (inverted and shown in black). Johnstone’s triangle codes are organized in descending order, with *Particulate* (dark gray) being the greatest and *Symbolic* (orange) being the least. Frequencies of *Macroscopic* (blue) and *Multiple Connections* (yellow) are also shown. Frequencies are listed at the bottom of each bar.

The *Particulate* level (106) was observed to be the greatest number, while *Symbolic* (3) was the least. We also detected *Macroscopic* (24) and *Multiple Connections* (12) codes that were approximately similar in number. All eight VCI-2 teachers included at least one instance of a *Particulate* code, while seven, four, and three referenced a *Macroscopic*, *Multiple Connections*, and *Symbolic* code, respectively. One example of feedback based on the *Particulate* level is, “I wasn’t sure about how many waters to draw vs. how many dissolved ions” (from Teacher 210 to 109). Another teacher stated that “[storyboarding] allows for students to “deep dive” into each change and really flesh out the full picture for students”, while another’s behest prompted a teacher to “explain why the single atom representation has an electron cloud around it” (from Teacher 109 to 206).

The main takeaway from the content analyses is the overwhelming number of *Particulate* codes and its prevalence among all eight VCI-2 teachers. Because of the extensive exposure to the VisChem Approach both from student and teacher perspectives,⁶⁰ VCI-2 teachers’ gravitation to the pedagogy was expected. The use of storyboards and VisChem animations throughout the microteaching may have calibrated VCI-2 teachers’ professional vision and shaped the content of their discourse.⁷⁷

Research Question 2: What Insights about Socio-pedagogical Norms Are Afforded by Juxtaposing the Nature and Chemistry Content of Teacher–Teacher Feedback Simultaneously?

We identified emergent patterns by comparing the overlaps between CF and JT codes. Figure 6 includes pie charts that show the frequencies of *Non-Chemistry* and *Chemistry-Specific* codes within each conversational function.

Praise was previously observed to be the most frequent CF code, while *Critique* was the least. Upon further inspection, comparing nature and content simultaneously showed a majority of *Praise* feedback being coded as *Non-Chemistry*, while all instances of *Critique* had *Chemistry-Specific* codes. Our analyses further indicated that conversational functions intended to change one’s own or another’s pedagogical practice (e.g., *Take Up*, *Suggest*, and *Critique*) either had closer ratios or leaned more toward *Chemistry-Specific* codes. Even *Elaborate*, which captures a VCI-2 teacher’s imagining and prospective thinking about pedagogical practice, consisted of more

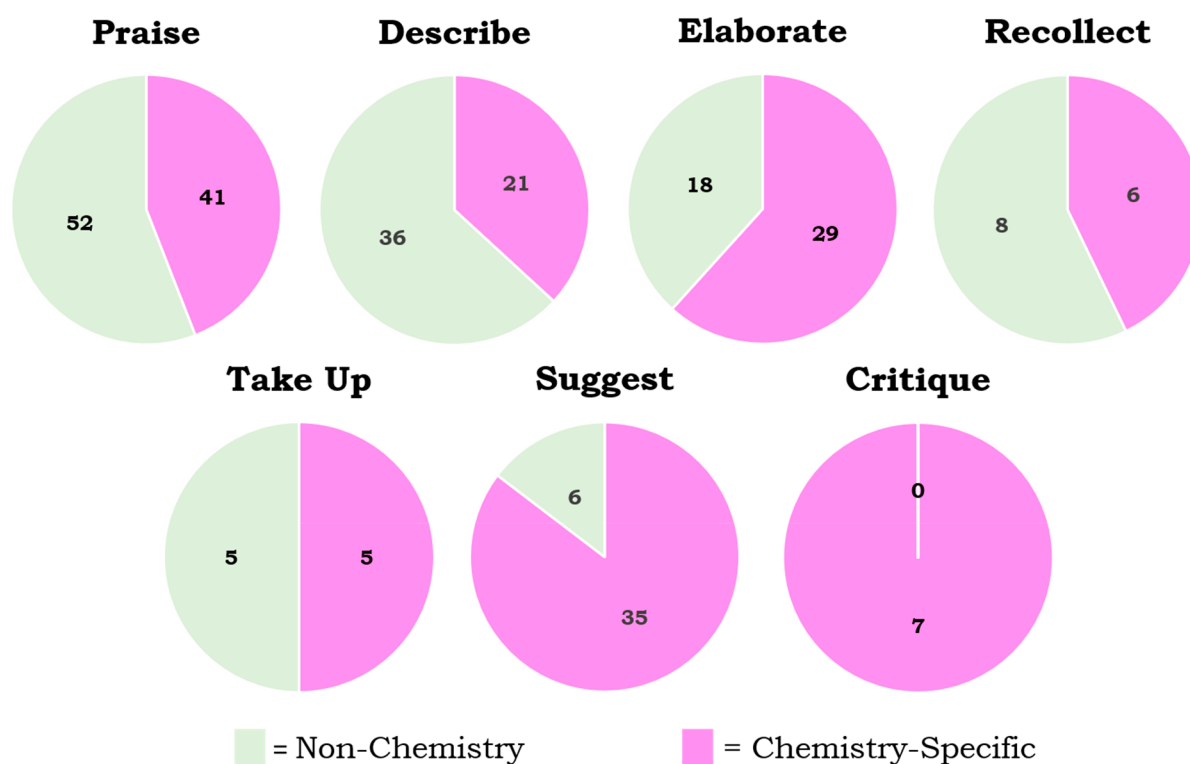


Figure 6. Pie charts showing the frequencies of *Non-Chemistry* (light green) and *Chemistry-Specific* (purple) codes, indicated as black numbers for each conversational function code for all VCI-2 teachers.

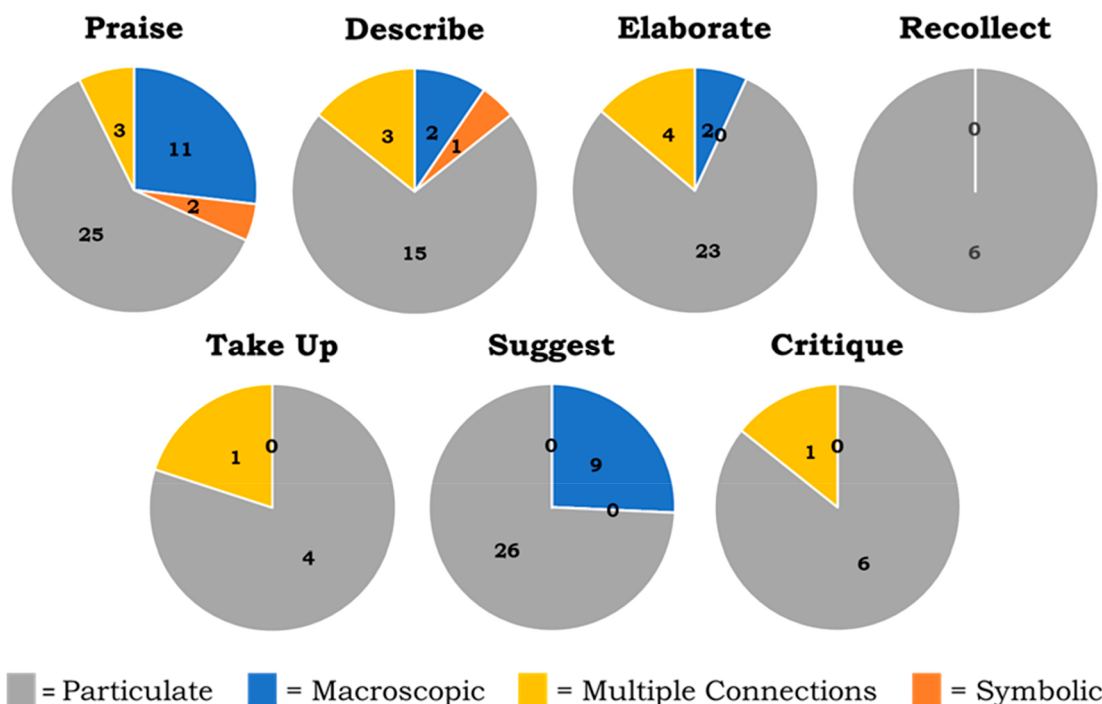


Figure 7. Pie charts showing the frequencies of *Particulate* (dark gray), *Macroscopic* (blue), *Multiple Connections* (yellow), and *Symbolic* (orange) codes for each conversational function code for all VCI-2 teachers. Each of the frequencies is shown as a black number, and their sum is equal to the total number of *Chemistry-Specific* codes for the respective conversational function.

Chemistry-Specific codes. The opposite is also true for conversational functions that are more descriptive and/or summative that do not explicitly pertain to reforming instruction (e.g., *Praise*, *Describe*, and *Recollect*). Thus, teacher stances that lean toward transforming pedagogical practice (e.g., *Suggest* and

Elaborate) have more chemistry-specific topics, while stances that do not explicitly indicate change encompass more ideas unrelated to chemistry. The connections between chemistry specificity and productive conversational functions may be a related principle when scaffolding and facilitating teachers'

provision of and engagement in critique. However, we remind readers that we do not assert a causal relationship given our current data and analyses. Determining causality between chemistry specificity and conversational functions is not this study's intent.

After isolating the *Chemistry-Specific* codes and examining each representational level, we noticed the various ways in which VCI-2 teachers melded the particulate level throughout their feedback. Figure 7 conveys pie charts with the frequencies of every JT code within each of the seven conversational functions.

Every *Chemistry-Specific* conversational function primarily consisted of *Particulate* codes. Although *Critique* had fewer instances than *Praise*, its composition of *Particulate* codes is noteworthy. The example, "I appreciate how your word choice and teaching practices reflected the various levels of skills and knowledge in your students" (*Praise – Non-Chemistry*, from 210 to 110) contrasts sharply with the excerpt "[We] didn't really revisit our particulate drawings afterward to change/revise them" (*Critique – Particulate*, from 106 to 109). Given that *Non-Chemistry* codes were previously shown to be nondescriptive and/or peripherally related to chemistry conceptual understanding, we noticed that teachers' comments related to the *Particulate* level included more detailed examples (e.g., changing and revising drawings of chemical phenomena) and were more frank in their ideas (e.g., criticizing how the drawings were not visited). Furthermore, the frequency of *Particulate* codes vastly outnumbered those of *Macroscopic*, *Multiple Connections*, and *Symbolic* codes in every conversational function. Although we cannot claim causality, we surmise that the *Particulate* level may be advantageous for PD. Explicit attention to molecular-level phenomena appears to be intertwined with a variety of teacher–teacher feedback, a noteworthy consideration when improving the accessibility of more difficult conversational functions.

Even though the VCI-2 did not use social protocols^{78–80} or explicitly establish socio-pedagogical norms for teacher–teacher feedback, prioritizing the molecular-level phenomena appears to be related to teacher critique and other conversational functions that engender instructional change. We speculate that the *Particulate* level, given its presence across all *Chemistry-Specific* conversational functions, could serve as a useful PD design principle that spans beyond the VCI-2 context. Drawing from the communities of practice literature¹⁰ as part of our ongoing discussion, focusing on molecular-level phenomena may be a key factor in the socio-pedagogical norms governing mutual engagement such that teachers can see each other as resources when providing/receiving feedback for reforming chemistry instruction.

With *Take Up*, *Suggest*, and *Elaborate* all having approximately 75% of *Particulate* codes, we interpreted that VCI-2 teachers were attending to, reflecting upon, and/or adapting the VisChem Approach for their respective classrooms. Some examples include "YouTube videos can be run at slower speeds. I suggest showing at full speed initially and then slowing to 0.25 speed, with teacher narration and stopping for clarification" (*Suggest – Particulate*, from 109 to GR) and "For such elaborate particle diagrams, it would be easier if [students] had keys provided" (*Suggest – Particulate*, from 209 to 110). For further context, these suggestions were teacher-generated ideas that were not prescribed when participants were initially taught how to implement the VisChem Approach. In other cases, teachers were excited to modify their extant practices. For example, a teacher expressed excitement to "use that methodology to guide students through other examples...video/demonstration, particulate

ulate drawing, and a connecting description" (*Take Up – Multiple Connections*, from 106 to 109). From a communities of practice perspective, these excerpts encompassed various components of the VisChem Approach's shared repertoire^{10,62} (e.g., storyboards, VisChem animations, and the cognitive learning model). Our findings suggest that socio-pedagogical norms did not just create awareness of a shared repertoire. Instead, we observed teachers' authoring these resources given the ways their feedback would tinker with theory and practice. Socio-pedagogical norms that encourage teacher agency may be associated with pedagogical customization and a shift away from a one-size-fits-all approach.

Had the nature and chemistry content of teachers' feedback been evaluated separately, the relationship between molecular-level phenomena and conversational functions would have gone unnoticed. As evidenced by the feedback analyses, VCI-2 teachers seem to be cognizant about how teaching pertains to chemistry learning as opposed to other commonly mentioned topics like classroom management, lack of curricular materials, or negotiations with district requirements.⁸¹ Our portrayal of the VisChem Approach, its purpose for advancing chemistry conceptual understanding, and its connection with NGSS may have contributed to emergent socio-pedagogical norms. Sadler⁸² noted that effective feedback entails an agreed-upon standard to which one can compare current level of performance. Aligning the VisChem Approach with NGSS practices throughout VCI-2 activities perhaps more clearly and meaningfully reified the goal of reform-based instruction. Centering a community of practice's joint enterprise¹⁰ around chemistry-specific practices related to the molecular phenomena could be positively associated with transformative feedback practices during professional learning.

SUMMARY OF RESULTS

The first phase of our analyses characterized the nature and chemistry content of teacher–teacher feedback on their peers' microteaching. Feedback excerpts primarily consisted of *Praise* with fewer instances of *Critique*. By applying Johnstone's triangle as an additional lens, *Chemistry-Specific* teacher–teacher feedback was largely identified as *Particulate* (104), while *Macroscopic*, *Multiple Connections*, and *Symbolic* had 24, 12, and 3 instances, respectively. The second phase of our analyses juxtaposed the nature and chemistry content simultaneously to garner additional insights regarding socio-pedagogical norms. Conversational functions such as *Praise*, *Describe*, and *Recollect* had more portions coded as *Non-Chemistry*. In addition, conversational functions that are more transformative (e.g., *Critique*, *Elaborate*, *Take Up*, and *Suggest*) had a similar, if not greater, ratio of *Chemistry-Specific* to *Non-Chemistry* codes. Furthermore, all *Chemistry-Specific* conversational functions consisted of *Particulate* codes. This pattern suggested that focusing on atoms, ions, and molecules may be a beneficial socio-pedagogical norm in chemistry professional learning settings.

IMPLICATIONS AND RECOMMENDATIONS

For Teacher Educators and Professional Developers

Our findings offer specific, accessible, and practical guidelines³² to identify, design, and facilitate transformative socio-pedagogical norms. On specificity, although studies have previously affirmed social protocols⁸⁰ (e.g., enabling the presenter to hear feedback without being on the defensive,

owning the work collectively, and ensuring equitable opportunities for all voices) and specific sentence stems (e.g., “I notice” and “I wonder”) to enhance teacher–teacher feedback,⁶⁷ much of this work lacked chemistry specificity. We propose an alternative, low-cost supplement that does not require a significant input of time or attention. Specifically, we recommend that teacher educators and professional developers explicitly frame feedback activities around chemistry-specific concepts in lieu of pervasive, nonchemistry topics.⁸¹ Doing so may be related to building socio-pedagogical norms that help teachers breach surface-level discourse and engage in conversational functions such as *Critique*, *Suggest*, *Elaborate*, and *Take Up*, in ways similar to what we had observed in our PD despite not using social protocols or sentence stems. In this manner, teachers can potentially achieve pedagogical discontentment⁵⁵ and catalyze their pedagogical conceptual change⁷ toward reform-based chemistry instruction.

Furthermore, all seven conversational functions (when filtered for chemistry specificity) were prominently characterized by the *Particulate* level. This vertex of Johnstone’s triangle may be more closely related to transformative socio-pedagogical norms than other representational levels like *Macroscopic* and/or *Symbolic*. We thus endorse foregrounding the behaviors of atoms, ions, and molecules in conversations about chemistry-specific instruction. Solely focusing on *Macroscopic* (e.g., laboratory demonstrations and experimental protocols) and/or *Symbolic* (e.g., written equations) may not be as useful for inviting teachers to adopt a critical stance on their peers’ and their own pedagogy.

On accessibility, we recommend teacher educators and professional developers attend to the components of a community of practice when configuring socio-pedagogical norms. Throughout the excerpts of teacher–teacher feedback, VCI-2 teachers had demonstrated instances of mutual engagement, use and authorship of shared repertoire, and adherence to joint enterprise. Based on our analyses of teacher–teacher feedback, we recognize the benefits of socio-pedagogical norms that collectively incentivize teachers to adapt an established pedagogy (i.e., the VisChem Approach) for their classrooms.⁸³ Cooper and Klymkowsky⁸⁴ previously stated that thinking about the curriculum itself as well as best ways to present the ideas and skills we envision students mastering should be prioritized. While we agree that the curriculum itself plays an intrinsic role, we add that fostering teacher agency and communal membership via transformative socio-pedagogical norms, especially through their critique via feedback, is also indispensable.

On practicality, our study’s focus on the nature and content of feedback can inform how research-based instructional strategies can be achieved at the undergraduate level,⁸⁵ outside of the VisChem Institute context. Namely, our ideas about productive socio-pedagogical norms may support chemistry graduate teaching assistants (GTAs). GTA training programs have historically been intensive⁸⁶ and focused on inquiry instruction as well as constructivist learning approaches.^{87,88} However, there is less attention on the social drivers behind GTA–GTA discourse during their professional learning. To catalyze transformative conversations in both nature and content, we recommend using our previously developed conceptual framework known as *pedagogical chemistry sensemaking*.⁸⁹ This theory moves beyond the conceptualization of Johnstone’s triangle as just a connection of representational levels. Instead, one must critique and discern the contextual limitations and utilities of one representational level to another for explaining phenomena.

We anticipate that centering socio-pedagogical norms around evaluating the synergies of Johnstone’s triangle can better prioritize both chemistry specificity and the *Particulate* level during feedback processes. Thus, for GTAs who may not have the time and resources to learn about the VisChem Approach, pedagogical chemistry sensemaking could be another practical option for enhancing socio-pedagogical norms that facilitate instructional change.

For Chemistry Education Researchers

While our attention to the nature and chemistry content of teacher–teacher feedback may be associated with the lowering of the “activation energy barrier” to achieving *Critique* and other transformative conversational functions, we note that there are other directions of feedback research that may be worthwhile for future studies. The context of the VCI-2 consisted of teachers providing feedback to their peers on two separate occasions. However, as recent studies have shown,^{22,79,90} exploring the dialogic nature (e.g., when teachers engage in further conversation about the feedback with each other) may be promising.

Understanding feedback as a dialogic endeavor means moving beyond the idea that feedback is the closure of loops and embracing the notion of a spiral. The ongoing nature of a spiral entails all involved parties actively tackling the long-term puzzle of teaching and learning.⁴⁵ This type of work has largely taken place in the context of instructional coaching, preservice teacher preparation, and interactions between in-service teachers. Thus, the socio-pedagogical norms that govern the nature and content of dialogic teacher–teacher feedback in chemistry-specific settings remain underexplored. Another exciting avenue of research is also investigating the dialogic feedback processes between teacher and student in chemistry-specific settings. Studies that investigate the complementary roles and shared responsibilities of instructor–learner dialogic feedback could more effectively foster agency and feedback literacy for both populations.^{74,91} Finally, whether one investigates teacher–teacher and/or teacher–student contexts, analyzing long-term dialogic interactions could more robustly elucidate the causal relationships between nature and chemistry content within provided feedback.

■ LIMITATIONS

We acknowledge that teachers’ feedback, as previously mentioned, has varying levels of precision in the meaning of its messages. We as researchers mitigated this limitation through our checks via weekly discussions, inter-rater agreement, and our holistic readings of the teachers’ feedback. We also carefully ensured that our iterative analyses of the feedback excerpts did not impose more precision on the interpretations than the data itself could offer. The scrupulous detail of our conversational function and Johnstone’s triangle codebooks thus enabled us to establish focused theoretical blinders so that our findings remained resonant with VCI-2 teachers’ ideas and useful for chemistry education research. Our inclusion of a *Non-Chemistry* code also assisted our categorization such that we could avoid reading too much into the data. Member checking can further enhance the trustworthiness of our work. Although the research team did not have an opportunity to follow up with teachers on their feedback, ongoing VCI-related work that examines what teachers are doing in their classrooms and the impact on their students are anticipated to build upon current PD findings.

Another limitation to this study is teacher–teacher feedback being the primary data source. The nature and content of the provided feedback could also have been attributed to how the instructions were presented during the VCI-2 and/or the extent of participants' familiarity with the SII format. First, we acknowledge that beyond describing strengths, improvements, and insights, there were no further cues from the PD facilitators that would have explicitly swayed teachers to frame their feedback positively or negatively. We as researchers were interested in teachers' initial predilections, most likely influenced by their prior experiences with providing feedback and/or engaging with their peers in professional learning settings. Second, while there were no visible indicators of confusion among teachers when writing their feedback, whether they fully understood the purpose and scope of the activities is uncertain. Nevertheless, we noticed that the two instances of feedback that each VCI-2 teacher provided did not have dramatic differences in their nature and content.

Context dependency may also constrain our work's transferability. We remind readers that VCI-2 participants had previously experienced VCI-related professional development (both formal and informal), with the research team as facilitators. The accumulation of learning about the VisChem Approach and its resources, NGSS, chemistry content, and the characteristics of other VCI teachers may have influenced the nature and content of the teacher–teacher feedback as well. In addition, how the feedback was provided was monologic (i.e., feedback was not delivered in the form of a back-and-forth conversation). Our findings thus cannot be directly transferred to spontaneous and informal feedback settings in which teachers take multiple turns when speaking. However, the observation that our findings still overwhelmingly consisted of *Praise* indicated that certain socio-pedagogical norms are difficult to surmount regardless of context. While our solutions may not immediately be applicable to other discursive modes in professional learning settings, we hope that our insights can elicit necessary discussions that delve deeper in the mechanisms and outcomes of teacher–teacher feedback.

CONCLUSIONS

The socio-pedagogical norms that sustain a community of practice are nuanced and may exist in contention with each other. On one hand, chemistry teachers' professional learning may be obstructed by their tendencies to remain courteous when providing feedback. On the other hand, not acknowledging the affective nature of the teaching profession would be remiss, as critique, if not properly directed, could diminish a teacher's self-efficacy. The same paradox can be observed in terms of the feedback's content. While our findings provide evidence that transformative, chemistry-specific teacher discourse largely consists of the particulate level, teachers should still be allowed to incorporate other content in their feedback so as to not constrain their agency and authoring. We as members of a chemistry education research community must then persist in our fine-grained inquiry of teacher discourse and identify ways of characterizing and dynamically adjusting socio-pedagogical norms. We should consider novel and relevant ways of responding to our chemistry teacher populations to best support their pedagogy and, ultimately, their students' conceptual understanding.

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Notes

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