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Advancing culturally relevant pedagogy in college chemistry

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Abstract: There is increasing emphasis on incorporating complex global challenges such as sustainable development and environmental justice in college chemistry instruction. Addressing these issues requires a community of engaged citizens who are empowered to enact change in their communities and value diverse perspectives. Culturally relevant pedagogy (CRP) is a framework that may support college chemistry faculty in integrating these social justice aims while also advancing equity within their own classrooms. However, college chemistry instructors' knowledge and implementation of CRP remains understudied. This research explores how college chemistry instructors (n = 6) from different institutions across the United States describe and operationalize CRP. Thematic analysis of semi-structured interviews indicates that the instructors in this study are flexible in their teaching approach, cultivate a classroom community of collaboration and belonging, and affirm that all students can be successful in chemistry. These practices are foundational elements of CRP, but they must also be coupled with knowledge of students' cultural backgrounds and awareness of sociopolitical issues that impact students. A framework that considers the context of college chemistry is proposed to support instructors' adoption of all of the tenets of CRP. Future work will further develop and examine the use of our framework for chemistry faculty development.

Keywords: culturally relevant pedagogy; faculty development; community cultural wealth; social justice

1 Introduction

Chemistry educators are uniquely positioned to facilitate students' understanding of many complex global challenges outlined in the United Nation's Sustainable Development Goals (Delaney et al., 2024; Stojanovska, 2024; United Nations, 2015). For example, chemical principles can be used to understand and address issues of water quality and climate change. However, teaching the core ideas of chemistry alone will not sufficiently support our society's ability to tackle these pressing issues. We must also empower students with the agency to enact change and advance equity in their local communities. To achieve this aim, we should first consider issues of equity within our chemistry classrooms.

The underlying culture of chemistry education reflects Western, Eurocentric ideologies (Younge et al., 2022), often causing students from different ethnic backgrounds to feel like they cannot engage in chemistry spaces as their authentic selves (McGee, 2016). Many scholars also implicate the culture of the academic environment for the disproportionate success outcomes observed across different demographic groups (Morton et al., 2023). For

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example, within the United States, the chemistry degree attainment of Black, Latine,[1] and Native American college students is disproportionate to their representation in the U.S. population (NCSES, 2023). Additionally, students frequently express their intent to use the skills and knowledge attained in chemistry (and other STEM classes) to address inequities and disparities in their home communities (McGee, 2021), but many college chemistry courses are taught in a way that is disconnected from these broader contexts (Cooper et al., 2017; Dessent et al., 2022; Flynn et al., 2019).

This highlights the critical need for a pedagogical shift in college chemistry that promotes more equitable student outcomes and supports students in leveraging the potentially transformative power of chemistry for social justice across culturally diverse contexts. One approach is to provide faculty development on implementing culturally-informed pedagogies in undergraduate chemistry education. Culturally relevant pedagogy (CRP) is one such pedagogical framework that aims to promote the academic achievement of culturally diverse students by positioning students' identities and experiences as intellectual resources and prioritizing the use of disciplinary knowledge to understand and critique relevant sociopolitical issues (Aronson & Laughter, 2016; Mathis et al., 2023a; Mensah & Larson, 2017).

1.1 Culturally relevant pedagogy

The global challenges that we seek to understand and address using the disciplinary core ideas of chemistry often affect diverse populations in different ways. Solutions to these challenges must account for the needs and values of the specific communities in which they are being enacted. Ultimately, this cultural awareness will foster a more inclusive and equitable approach to the sustainable development goals that are relevant to communities worldwide. Similarly, chemistry educators should consider the cultural backgrounds of their students to promote more equitable learning experiences and support the development of student's cultural competence.

In this study, we operationalize culture as the collective norms, practices, values, and beliefs that shape the identities and behaviors of a particular group or community. In the classroom, this can be observed in how students from different cultural backgrounds communicate and engage in classroom activities (Mathis et al., 2023b). For example, some students may belong to cultural groups that prioritize collectivism and collaborative learning, while others may relate to a more individualistic and competitive approach to learning (Hammond, 2015; Mathis et al., 2023b). Gloria Ladson-Billings defines culturally relevant educators as those who "advance student learning, develop cultural competence, and foster critical consciousness" (Ladson-Billings, 2021a, p. 351). When these classroom qualities are present simultaneously, students can "maintain their cultural integrity while succeeding academically" (Ladson-Billings, 1995, p. 476).

Ladson-Billings also identified several commonalities in the beliefs and ideologies of culturally relevant educators. Culturally relevant educators view every student as capable of success and approach their teaching practice as an art that can continually be refined (Ladson-Billings, 1995). Culturally relevant educators prioritize maintaining relationships with students that are humanizing and equitable and commit to developing a positive and collaborative classroom culture because they believe that knowledge is shared and constructed in community (Ladson-Billings, 1995). Culturally relevant educators also value using multiple and varied assessments for students to demonstrate their knowledge (Ladson-Billings, 1995). These attitudes and dispositions are foundational for the three tenets of CRP: *student learning, cultural competence,* and *sociopolitical (or critical) consciousness* (Ladson-Billings, 1995, 2021b).

Student learning refers to attending to students' academic needs by communicating high expectations for all students and building on the knowledge and strengths students bring to the classroom (Ladson-Billings, 1995). This is characterized by student-centered instruction, student-led discourse, and student collaboration that motivates students to learn and engage in the challenging and productive work needed for long-term success (Mathis et al., 2023a). Cultural competence addresses supporting students in recognizing diverse cultural beliefs

1 Gender-neutral demographic term for people from Latin America. Individuals within this community may also use the terms Latino/a, Latinx, or Hispanic.

and practices as they engage in disciplinary-specific thinking (Ladson-Billings, 1995). This tenet must be merged with student learning to empower students to engage in the classroom as their authentic selves, which is essential for their academic success and psychological well-being (Ladson-Billings, 1995; Mathis et al., 2023a). Sociopolitical consciousness refers to enhancing students' ability to engage in the world critically and using content knowledge to understand and address social justice issues (Ladson-Billings, 1995).

CRP has been studied across several physical science contexts including secondary chemistry and physics (Mathis et al., 2023a; Morales-Doyle, 2017; Rüschenpöhler et al., 2024). There are also a few examples of instructors using tenets of CRP in college chemistry courses. Landis (2024) designed a first-day activity that prioritized student collaboration and explored how analytical chemistry could be used to understand and address a local water quality crisis. McCarthy et al. (2020) also designed a biochemistry lesson to support students' ability to analyze protein structures and learn about the sickle cell disease that disproportionately impacts people of African descent. Hollond et al. (2022) developed a biochemistry course that explored disparities in medical access and health outcomes within the local community.

However, to our knowledge, no existing framework specifically supports college chemistry instructors in understanding, adopting, and implementing the full CRP framework within their discipline. Therefore, this exploratory study examines how chemistry instructors at colleges and universities within the United States describe and operationalize CRP.

1.2 Research question

The research question that informed our qualitative study was: *How do college chemistry instructors describe and operationalize culturally relevant pedagogy in undergraduate chemistry courses?*

2 Research methods

In this exploratory study, we conducted semi-structured interviews with six college chemistry instructors to gain more insight into how they understand and actualize CRP (if at all) in their classrooms.

2.1 Recruitment and participants

We recruited instructors through a multi-institution STEM education project that we are currently collaborators on. This project explores partnerships between institutions to support equitable outcomes for transfer students in STEM. Transfer students complete some coursework at one institution and then transfer to another institution to complete their degree requirements. We released a call through this project network seeking active college chemistry instructors with interest and/or experience in culturally relevant teaching to participate in interviews on culturally relevant chemistry instruction. However, participants did not have to be from an institution affiliated with the larger project. Three of the six instructors who volunteered to participate were from institutions associated with the ongoing project, and three were not. It is also important to note that none of the participants in this study were our direct collaborators on the larger multi-institution project.

This study was approved by the Institutional Review Board, and informed consent was obtained from all participants prior to their voluntary participation. Participants also verbally consented to the recording of their audio during their interview. Participants were informed that their interview responses would be anonymized. Thus, we report their demographic and teaching background information in aggregate to ensure anonymity. The college chemistry instructors were three women and three men who identified racially or ethnically as Hispanic and/or white. The participants' instructional experience varied from two to more than 25 years. A variety of teaching contexts were also represented, including a public community college and a private liberal arts college in the midwestern U.S., as well as a research-intensive university in the southwestern U.S. These post-secondary

institutions within the United States typically vary in enrollment size and types of degrees awarded. Most community colleges award two-year undergraduate degrees and provide vocational training, liberal arts colleges primarily award four-year undergraduate degrees, and research-intensive universities award both undergraduate and graduate degrees.

2.2 Data collection

Each instructor participated in one semi-structured interview. All interviews were conducted by Author 1, and a second researcher was present during each interview to capture notes. The interview protocol (see Supplementary Material) was designed to learn about each instructor's teaching context, their understanding of CRP, and how they implement or envision CRP being applied in their context. The interview questions were shared with participants in advance to build trust and transparency, and at the beginning of each interview session, an explanation of the study was provided.

To develop rapport with participants, the first few interview questions focused on their teaching background. Participants were also able to select which course they wanted to focus on for the interview. All participants selected the general chemistry or organic chemistry lecture course that they were actively teaching at the time of the interviews. To better understand their teaching contexts, we asked participants to describe their class sizes and the racial and linguistic diversity of their students in the course of interest. We also asked questions about their general instructional approach, including how they get to know their students, what a typical day looks like in their class, and some of their favorite course activities.

Then, we explicitly shifted to questions related to culturally relevant chemistry teaching. Since instructors with any level of interest or experience with CRP were invited to participate in the study, we asked them to rank their experience level ranging from "heard or read about CRP" to "have used culturally relevant teaching practices." Given that our research objective was to explore chemistry instructors' understanding of CRP, we did not use language from the CRP framework, such as cultural competence or sociopolitical consciousness, in the interview questions unless a participant introduced it first. Our semi-structured interview protocol provided this flexibility.

To elicit instructors' understanding of CRP we asked what culturally relevant instruction meant to them. We also posed hypothetical teaching scenarios to understand how instructors might apply the principles of CRP in their classrooms and adapt a lesson plan to be more aligned with CRP. If instructors already had examples of lessons or activities that aligned with CRP, they were able to share them as well. Finally, we asked instructors to describe any challenges or barriers they perceive (or have experienced) to implementing a culturally relevant teaching approach.

Interviews purposefully concluded with demographic information as we did not want to prime participants to consider their social identities when describing their pedagogical decisions. All interviews were conducted and recorded via Zoom and lasted approximately 45 min.

2.3 Data analysis

Our qualitative data analysis was guided by reflexive thematic analysis (Braun & Clarke, 2006). A similar analytical approach has been used in other recent exploratory studies that utilized semi-structured interview data with faculty (Mathis et al., 2023a; Parker et al., 2023). We found reflexive thematic analysis appropriate for the organization, identification, and analysis of emergent themes from our exploratory interview data set (Braun & Clarke, 2006).

Reflexive thematic analysis is a six-phase analytical process meant to be approached recursively and iteratively (Byrne, 2022). As such, we cycled between and through the phases several times during the analytical process (Braun & Clarke, 2006). In the first phase, *data familiarization*, each interview was transcribed verbatim and uploaded in MAXQDA, a qualitative data analysis software. The transcripts were reviewed several times by

both authors and during these initial read-throughs, interesting observations related to the research question were captured. The second phase began with an inductive, open *coding* approach to further support data familiarization. Author one coded each interview transcript, but credibility was established through several coding meetings with Author two and other colleagues to discuss the anonymized data. The third and fourth phases consisted of *generating and reviewing initial themes*. After generating themes using the inductive coding approach, we re-coded the data using a refined codebook consisting of the tenets of CRP as well as codes related to the initial themes. In the final phases of RTA, the themes were finalized, *defined* and *reported*.

2.4 Researcher positionalities

Author one identifies as a Black woman with a background in chemistry and chemistry education. She is a general chemistry instructor at a research-intensive university in the southeastern United States and a collaborator on STEM education research projects where she conducts interviews with students and faculty in different contexts. Her own educational experiences at predominantly white institutions motivated her open investment in the success and well-being of students who are numerically underrepresented in chemistry. This aligns with the transformative paradigm's focus on challenging inequities and promoting social change through research. Author two identifies as a white queer man with a disciplinary background in mathematics and is an assistant professor of STEM education. He recognizes that his identity and experiences, particularly navigating the heteronormative culture often prevalent in STEM fields, provide him with a critical lens for analyzing power dynamics and advocating for inclusive pedagogies. This perspective aligns with the transformative paradigm's emphasis on critiquing oppressive systems and empowering marginalized voices. Our experiences and positionalities as both insiders (emic) and outsiders (etic) with respect to pedagogy in teaching chemistry were leveraged to interpret and understand the perspectives of the instructors in this study. By acknowledging our own social locations and potential biases, we aim to conduct research that is not only rigorous but also ethically grounded and socially responsible, contributing to a more just and equitable learning environment for all students.

2.5 Limitations

Due to the qualitative nature of our exploratory study with six participants, our findings should not be generalized to all college chemistry faculty. Rather, this provides a starting point for understanding how some college chemistry instructors view CRP and the support that may be needed to support more widespread adoption and implementation. Additionally, three of the six participants in this study were from institutions involved in a research network that seeks to advance equitable outcomes for transfer students in STEM. As such, these instructors may have a more equity and asset-based teaching orientation that shapes their perceptions of CRP. However, all of the instructors in this study identified their existing interest or experience with CRP. To answer our research question, we wanted to consider how chemistry instructors already attending to CRP understand and enact it within their local teaching context, so it is important to note the influence of these factors on our results.

3 Results and discussion

Given the paucity of studies in this context, we conducted an exploratory study on college chemistry instructors' understanding of and use of CRP. The semi-structured interview approach allowed us to collect data in a uniform manner while having the flexibility to shift the line of questioning when needed to better understand each instructor's unique experiences with CRP. Three major themes emerged from our analysis of how college chemistry instructors describe and operationalize CRP in undergraduate chemistry courses. These include 1)

instructor efforts to cultivate a collaborative classroom community, 2) instructor efforts to build relationships with students, and 3) instructor efforts to affirm the intellectual capacity of students. Each of these themes is related to instructors' actions and behaviors that we identified to align with tenets of CRP.

3.1 Cultivating a collaborative classroom community

One way the instructors in this study operationalized CRP was by fostering a culture of collaboration where diverse learners can learn and grow together. During their interviews, five instructors discussed the importance of providing opportunities for students to talk and work together in their lecture courses. The size of these instructor's lecture courses varied from 40 to more than 200 students, but they all encouraged some form of group or peer learning.

One instructor noted that structuring their class in small groups allowed them to monitor student progress more efficiently and provide personalized attention. "I can get to each group fairly easily when they're working on problems and make sure they are on the right track, whereas if they are doing stuff individually, students are struggling, and I don't even notice because they are not talking to anyone." A different instructor shared that prior to exams, they provide an in-class review worksheet for students to work on in groups, and they walk around and answer their specific questions during the class period. However, they stated that "the configuration of their classroom has long rows of tables that are not conducive for small group work." A third instructor also uses worksheets for one of their three weekly class meetings with students and has students work in groups to complete them.

In addition to worksheets, another structure utilized consistently for small group work was process-oriented guided inquiry learning (POGIL) tasks (Farrell et al., 1999). In POGIL tasks, students work in self-managed teams of 4–6 students to construct an understanding of a new concept (Farrell et al., 1999). Students typically are assigned specific roles such as reader, reporter, and manager, and the instructor acts as the facilitator, providing clarification and posing questions to teams of students as they work. The instructors who implemented POGIL tasks mentioned that they set the tone for this type of active student engagement from the first day of class.

> The first day of class is just about how you bring community into the class. I give each student a card with facts about each student in the class that I collected from a pre-class survey. They spend the class period finding the person who matches each fact. Then, they have space to write down the email addresses of other students and build a study group that way.

The instructors in this study encourage students to get to know each other early in the course and are explicit about how engaging in collaborative work is an essential skill. Instructors in teaching contexts with larger class sizes did not discuss using POGIL tasks but utilized activities where students "turn and talk" with a classmate sitting in proximity. When asked how peer learning and group work support culturally relevant chemistry instruction, one instructor expressed,

> So much of the US and STEM culture is individualized and in competition. Working in groups where some people might come from a culture that is really more group and communication-focused is culturally relevant.

3.2 Building relationships with students

Another cross-cutting theme in the instructor interviews was instructors' efforts to establish a classroom culture of care and respect by building relationships with students. All six instructors identified that to teach in a culturally relevant way they must get to know their students and care for them as whole people, not just as students. One instructor described their approach to CRP by sharing, "enjoying them as people and getting to know them is a really big part." Instructors also talked extensively about adapting their instructional approach based on the backgrounds that they learned about the students in their classes. "Each year you figure it out and adapt to what students need."

In order to build relationships with students, one instructor shared how they start their courses,

I ask students early on during the first week of class to write some information about themselves, and I read over it after class. I also share about myself to give them insight into who I am.

All of the instructors talked extensively about the importance of office or student hours, which allow students to meet with them outside of formal class time. One instructor shared that office hours were the only way to get to know students in their largest class which had 170 students enrolled. "Basically, the students that I do get to know are the ones who come to office hours." A different instructor shared how they make being available for students a priority in their workday,

> I see students a lot in my office, but that's the best part of the job. Maybe I haven't graded everything yet, but will I grade the quiz or meet with a student who needs support? I'm going to meet with the students.

Other instructors also shared that being approachable outside of class and responsive to student e-mails helped foster strong relationships with the students in their courses.

Another approach for building relationships with students that was observed across the instructor interviews was humanizing instruction. The instructors often started their classes with check-in questions unrelated to chemistry to prioritize students' well-being. An instructor who recorded video lectures for their classes shared that they would always keep their camera on and share interesting facts about themselves to help students get to know them and keep them engaged in the videos.

It was evident that the instructors cared about building relationships with students to support their holistic success and were not primarily interested in their academic performance. One instructor quote exemplifies this noticing,

> Chemistry should never be the most important thing. And I think that saying that to them, which I do, is important. You know the most important thing in your life is you.

3.3 Affirming the intellectual capacity of students

Another central theme that emerged from instructor interviews was a belief that all students are capable of excellence in chemistry and promoting a growth mindset in their classroom. The instructors were explicit with their students that their chemistry knowledge is not fixed, and they can grow their ability to engage in really challenging chemistry concepts with time and practice.

This informed their teaching approach as well, which we found to be very flexible in terms of how they were teaching and the types of assignments they gave students to support their understanding. There was a high degree of instructor attention to what and how they taught to promote students' academic achievement. For example, one instructor said, "Teaching chemistry the way we were taught just doesn't make sense. Nothing is sacred in that way." Many instructors also described how they are intentional that students "experience a win in chemistry early on," so they are motivated to persist.

When instructors talked about their students, we also noticed this affirmation of their intellectual capacity because they took a very asset-oriented approach focusing on building on the skills students already had to support their growth instead of deficit framing, which focuses on skills and abilities students may lack. There was an explicit focus on student success. When describing their instructional approach, one participant stated, "I want all of my students to succeed." A different instructor acknowledged that success means different things for each student but ultimately wants all students to have a positive experience in chemistry. A final example that summarizes this theme was an instructor describing how they are transparent with students about not trying to "weed them out." They want students to finish the course with "critical thinking and logical reasoning skills that will be more enduring than remembering what an acidic proton is."

3.4 Challenges of CRP in college chemistry

The analysis of instructor interview data also revealed several barriers to the effective implementation of CRP. Some instructors perceived their department's emphasis on course coordination (the synchronization of instruction and assessments among instructors of the same course) was prohibitive. When discussing an idea to modify the course assessment structure to be more culturally relevant, an instructor said, "This would probably get me kicked out of the department." A different instructor mentioned that they would wait until tenured to fully adopt a more culturally relevant teaching approach, noting that it would not only be in resistance to their prevailing departmental culture but would also require time and resources that they do not have as an early-career professor.

Another common challenge described was the pressure of content coverage and standardized final exams. The general chemistry instructors particularly felt like they were "teaching to the test" and did not have time in their curriculum to effectively incorporate CRP. Instructors with more flexibility in their curriculum explained the challenge of finding evidence-based research on how to authentically teach chemistry in a culturally relevant way. An instructor shared, "I not only need an adapted curriculum, but actual reflections from instructors that describe best practices for doing this."

Overall, the instructors understood that the foundation of being a culturally relevant practitioner is built on having strong knowledge of their students, but instructors in large-enrollment course contexts questioned how to get to know their students and tailor instruction to their interests. One instructor mentioned that they only get to know the students that attend office hours. Another instructor was interested in providing more student choice in assessments but recognized that "grading 100 different assessments would not be feasible" and wondered how to make culturally relevant teaching approaches scalable for their large sections.

We find that the challenges that the instructors in our study identified are consistent with the perspectives of STEM instructors more broadly (Xie & Ferguson, 2022). In a recent study, Xie and Ferguson (2022) conducted focus groups with faculty across all STEM disciplines to better understand their perspectives on adopting culturally responsive pedagogy. Culturally responsive pedagogy is an asset-based pedagogical framework with many similarities to CRP, but they differ in that CRP has a sociopolitical consciousness aspect aimed toward increasing social justice (Gay, 2002; Mensah & Larson, 2017). Despite using a different culture-based pedagogical framework, Xie and Ferguson (2022) also reported that creative solutions to incorporate CRP are needed to address challenges such as low departmental support, lack of time and resources, and building community in large-enrollment courses.

One suggestion that instructors may consider when navigating these barriers is starting with a small structure that can be used repeatedly throughout the course. Ali et al. (2020) describe how they begin at least one lecture per week with a discussion of a molecule of interest. "Each compound was introduced to students along with its background and some of the effects beyond intention, from regulatory issues to environmental pollution. We aimed to briefly highlight how organic chemicals can be an instrument for enhancing equity, simultaneously stimulating awareness of the injustices and injuries that can be promoted by the misuse of chemicals" (Ali et al., 2020, p. 3985). In this structure that takes approximately 5 min of class time per week, chemistry instructors are able to attend to the sociopolitical consciousness and student learning domains of CRP. Cultural competence may also be addressed if instructors select molecules that have significance to different cultural groups or highlight the use or impact of the molecule within different communities. Ali et al. (2020) also discuss how they incorporate the molecules presented at the start of class in reactions and example problems in lectures and on assessments to extend students' learning and recognition of these molecules.

The tensions that chemistry faculty experience between content coverage and adopting more student-centered instructional strategies have also been well-documented (Kraft et al., 2023; Shadle et al., 2017). Petersen et al. (2020) outline strategies that can be used to navigate these tensions and shift from a teacher-centered, content coverage approach to a more student-approach. Interestingly, one strategy is to organize and develop course content around themes that are relevant to students' lives.

3.5 Supporting college chemistry instructors understanding of CRP

The instructors in our study named several challenges and barriers to implementing CRP in the context of college chemistry. However, they still wanted support in learning to be more culturally relevant chemistry instructors. CRP is organized around three major domains: student learning, cultural competence, and sociopolitical consciousness (Ladson-Billings, 1995). The framework intends for these classroom qualities to be implemented simultaneously to foster spaces where students can experience academic success and maintain their cultural integrity and well-being (Ladson-Billings, 1995). When examining the major themes from our study, we noticed that the college chemistry instructors predominantly described and operationalized CRP with a focus on the student learning domain. Facilitating group work, building relationships with students, and promoting a growth mindset have all been identified as practices aligned with the student learning domain of CRP (Ladson-Billings, 1995). However, our results revealed few practices that aligned with the cultural competence and sociopolitical consciousness domains of the CRP framework. Although there was no clear evidence of the instructors in our study incorporating knowledge of students' cultural capital and relevant sociopolitical issues, the instructors articulated a desire to increase the cultural relevance of their content. One instructor stated,

> Cultural relevance is being aware of where your students are coming from and making sure chemistry is not siloed. It is the study of the natural world and humans, our emotions, and our biases are part of that, so we need to incorporate that into the class because who are the scientists? Humans.

As a result of this finding, we propose an instructional framework to support college chemistry instructors' holistic implementation of CRP. Our proposed framework builds on the traditions of both culturally relevant pedagogy and community cultural wealth (CCW) (Ladson-Billings, 1995; Yosso, 2005). CCW is an asset-based theoretical framework that names and identifies six forms of cultural capital that students of color possess (Figure 1) (Yosso, 2005). We believe that introducing college chemistry instructors to CCW may support them in integrating all three domains of CRP into their practice by elevating and affirming the cultural capital of their students. This framework is not designed to be a blueprint for implementing CRP but a starting point for meaningful reflection. Ladson-Billings cautions against prescriptive approaches to faculty development on CRP (Ladson-Billings, 1995). The guiding questions, coupled with examples from the literature or instructors in our

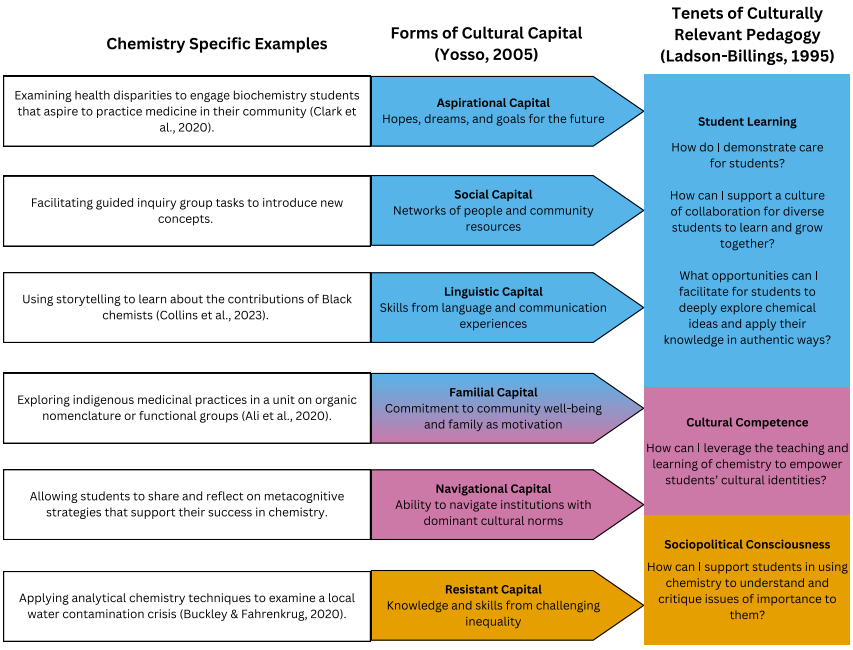

Figure 1: An instructional framework aligning community cultural wealth and culturally relevant pedagogy to expand college chemistry instructors' implementation of CRP.

study, are intended to aid college chemistry instructors in using all three domains of CRP to inform classroom practices (Figure 1).

To utilize our adapted framework, instructors should start by recognizing the forms of cultural capital that their students possess. For example, linguistic capital refers to the skills that students already possess from experiences using more than one language or communication style. Next, instructors should consider how to elevate those cultural resources in their classroom practices. When thinking about students' linguistic capital, a question that could be considered when planning for instruction is, "What opportunities can I facilitate for students to explore chemical ideas and apply their knowledge in a way that affirms their linguistic skills and experiences?" One exemplar of building on students' linguistic capital in the chemistry classroom is through the use of storytelling. Many cultures have rich traditions of passing history and knowledge through oral stories. Collins et al. (2023) described how they have used storytelling to engage students in critical thinking related to chemical concepts.

This reflection process outlined in our framework could be referenced to guide the development of a single lesson or when planning for a complete unit in a course. The specific examples and references provided in Figure 1 represent several chemistry courses to show the frameworks' utility for a range of courses. It may not be feasible to build on every form of students' cultural capital in every lesson, but the goal is to always consider all three domains of CRP in planning for instruction.

4 Conclusions

We explored how college chemistry instructors describe and operationalize CRP. Our analysis reveals that many instructors are cultivating learning environments that support the success and engagement of culturally diverse students but may require learning opportunities on how to fully implement all tenets of CRP within the context of college chemistry. Specifically the sociopolitical consciousness and cultural competence domains of the pedagogical framework. As such, we proposed aligning community cultural wealth and CRP to help instructors engage CRP in its full capacity. In the future, we plan to examine the effectiveness of this approach for chemistry faculty development on CRP.

Our work also identified structural barriers to college chemistry instructors' adoption of CRP. We hope that instructors give themselves grace when working to implement principles of this framework and recognize that starting with a single lesson or activity is a meaningful step forward. Our proposed framework aligning community cultural wealth and CRP can also be used as a reflective tool to support moving forward with CRP in the college chemistry context.

Future work should aim to mitigate these barriers to the adoption and implementation of CRP. Specifically, there is a demand for quality design-based implementation research to develop curricular materials aligned with CRP and explore best practices for implementation. Research investigating the impact of CRP on students' academic and affective outcomes in college chemistry is also needed. It is imperative that the college chemistry education community actively engages in this work to create chemistry learning environments where all students can thrive and are empowered to use their knowledge of chemistry to solve and understand the issues that are relevant to their communities.

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References

Ali, Z., Harris, V., & LaLonde, R. (2020). Beyond green chemistry: Teaching social justice in organic chemistry. *Journal of Chemical Education*, *97*(11), 3984–3991.
Aronson, B., & Laughter, J. (2016). The theory and practice of culturally relevant education: A synthesis of research across content areas. *Review of Educational Research*, *86*(1), 163–206.
Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101.
Byrne, D. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity*, *56*, 1391–1412.
Collins, S., Steele, T., & Nelson, M. (2023). Storytelling as pedagogy: The power of chemistry stories as a tool for classroom engagement. *Journal of Chemical Education*, *100*(7), 2664–2672.
Cooper, M. M., Posey, L. A., & Underwood, S. M. (2017). Core ideas and topics: Building up or drilling down?. *Journal of Chemical Education*, *94*(5), 541–548.
Delaney, S., Chiavaroli, L., Dissanayake, T., Pham, L., & Schultz, M. (2024). International teacher survey on green and sustainable chemistry (GSC) practical activities: Ddesign and implementation. *Chemistry Teacher International*, *6*(3), 295–309.
Dessent, C. E., Dawood, R. A., Jones, L. C., Matharu, A. S., Smith, D. K., & Uleanya, K. O. (2022). Decolonizing the undergraduate chemistry curriculum: An account of how to start. *Journal of Chemical Education*, *99*(1), 5–9.
Farrell, J. J., Moog, R. S., & Spencer, J. N. (1999). A guided-inquiry general chemistry course. *Journal of Chemical Education*, *76*(4), 570–574.
Flynn, A. B., Orgill, M., Ho, F. M., York, S., Matlin, S. A., Constable, D. J. C., & Mahaffy, P. G. (2019). Future directions for systems thinking in chemistry education: Putting the pieces together. *Journal of Chemical Education*, *96*(12), 3000–3005.
Gay, G. (2002). Preparing for culturally responsive teaching. *Journal of Teacher Education*, *53*(2). https://doi.org/10.1177/0022487102053002003.
Hammond, Z. L. (2015). *Culturally responsive teaching and the brain*. Thousand Oaks, California: Corwin Press.
Hollond, C., Sung, R. J., & Liu, J. M. (2022). Integrating antiracism, social justice, and equity themes in a biochemistry class. *Journal of Chemical Education*, *99*(1), 202–210.
Kraft, A., Popova, M., Erdmann, R. M., Harshman, J., & Stains, M. (2023). Tensions between depth and breadth: An exploratory investigation of chemistry assistant professors' perspectives on content coverage. *Chemistry Education Research and Practice*, *24*, 567–576.
Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*, 465–491.
Ladson-Billings, G. (2021a). Three decades of culturally relevant, responsive, & sustaining pedagogy: What lies ahead?. *The Educational Forum*, *85*(4), 351–354.
Ladson-Billings, G. (2021b). I'm here for the hard re-set: Post-pandemic pedagogy to preserve our culture. *Equity & Excellence in Education*, *54*(1), 68–78.
Landis, E. C. (2024). Flint, Michigan, water crisis as an upper-division first day of class activity and introduction to primary literature. *Journal of Chemical Education*, *101*(5), 2162–2166.
Mathis, C., Daane, A., Rodriguez, B., Hernandez, J., & Huynh, T. (2023b). How instructors can view knowledge to implement culturally relevant pedagogy. *Physical Review Physics Education Research*, *19*, 010105.
Mathis, C., Southerland, S. A., & Burgess, T. (2023a). Physics teachers' dispositions related to culturally relevant pedagogy. *International Journal of Science Education*, 1–20. https://doi.org/10.1080/09500693.2023.2190850.
McCarthy, P., Williams, R., Hughes-Darden, C., Ellington, R., Mayaka, P., Jackson, M., & Nkwanta, A. (2020). Using molecular visualization as a tool for culturally competent and culturally relevant teaching: A guided-inquiry biochemistry activity. *The Journal of Computational Science Education*, *11*(2), 2–6.
McGee, E. O. (2016). Devalued Black and Latino racial identities: A by-product of stem college culture?. *American Educational Research Journal*, *53*, 1626–1662.
McGee, E. O. (2021). *Black, Brown, bruised: How racialized STEM education stifles innovation*. Cambridge, MA: Harvard Education Press.
Mensah, F. M., & Larson, K. (2017). *A summary of inclusive pedagogies for science education*. Washington, DC: The National Academies of Sciences, Engineering, Medicine.
Morales-Doyle, D. (2017). Justice-centered science pedagogy: A catalyst for academic achievement and social transformation. *Science Education*, *101*, 1034–1060.
Morton, T. R., Agee, W., Ashad-Bishop, K. C., Banks, L. D., Barnett, Z. C., Bramlett, I. D., Brown, B., Gassmann, W., Grayson, K., Hollowell, G. P., Kaggwa, R., Kandlikar, G. S., Love, M., McCoy, W. N., Melton, M. A., Miles, M. L., Quinlan, C. L., Roby, R. S., Rorie, C. J., …, Woodson, A. N.

(2023). Re-Eenvisioning the culture of undergraduate biology education to foster Black student success: A clarion call. *CBE-Life Sciences EducationCBE—Life Sciences Education*, *22*(4), es5.

National Center for Science and Engineering Statistics (NCSES) (2023). Diversity and STEM: Women, minorities, and persons with disabilities. https://ncses.nsf.gov/pubs/nsf23315.

Parker, A., Noronha, E., & Bongers, A. (2023). Beyond the deficit model: Organic chemistry educators' beliefs and practices about teaching green and sustainable chemistry. *Journal of Chemical Education*, *100*(5), 1728–1738.

Petersen, C. I., Baepler, P., Beitz, A., Ching, P., Gorman, K. S., Neudauer, C. L., Rozaitis, W., Walker, J. D., & Wingert, D. (2020). The tyranny of content: "Content coverage" as a barrier to evidence-based teaching approaches and ways to overcome it. *CBE-Life Sciences EducationCBE Life Sciences Education*, *19*(2), 17.

Rüschenpöhler, L., Schneider, M., & Markic, S. (2024). Secondary school teachers' beliefs about the role of culture in chemistry class and their ways of considering and engaging in it. *Journal of Chemical Education*, *101*(10), 4083–4092.

Shadle, S. E., Marker, A., & Earl, B. (2017). Faculty drivers and barriers: Laying the groundwork for undergraduate STEM education reform in academicdepartments. *International Journal of STEM Education*, *4*, 1–13.

Stojanovska, M. (2024). Integrating ethics and democratic principles in chemistry education: Aa case study. *Chemistry Teacher International*. https://doi.org/10.1515/cti-2024-0010.

United Nations (2015). Sustainable development goals: 17 goals to transform our world. https://sdgs.un.org/goals.

Xie, J., & Ferguson, Y. (2022). STEM faculty's perspectives on adopting culturally responsive pedagogy. *Teaching in Higher Education*, 1–19. https://doi.org/10.1080/13562517.2022.2129960.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race, Ethnicity and EducationRace Ethnicity and Education*, *8*(1), 69–91.

Younge, S., Dickens, D., Winfield, L., & Sanders Johnson, S. (2022). Moving beyond the experiment to see chemists like me: Cultural relevance in the organic chemistry laboratory. *Journal of Chemical Education*, *99*(1), 383–392.

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