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Building a Community of Practice: A Case Study of Introductory College Chemistry Students

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Abstract

Engagement in active learning and learning communities is important for persistence of STEM students early in their academic programs. Colleges and universities have an ongoing call to facilitate active learning techniques, yet large group, lecture-based instruction is still the prominent method of instruction. This qualitative case study examines interviews and classroom observations of undergraduate chemistry students enrolled at a primarily undergraduate institution. Critical educational elements were identified for chemistry students participating in a redesigned, introductory course which included a collaborative peer-lead learning experience. The participants engaged in required, weekly sessions structured around community building and active learning. The data were framed through a Community of Practice (CoP) framework and emergent themes were centered on the following components: mutual engagement, joint enterprise, and shared repertoire. Findings show participant engagement created opportunities for collaboration beyond the required, weekly sessions, which included forming study groups and seeking assistance from chemistry tutors. Participants also shared study techniques based on a mutual understanding that effective learning required routine practice. Implications for STEM departments and researchers about implementing research-based curriculum are discussed.

Keywords: community of practice, undergraduate, STEM curriculum, case study

Building a Community of Practice: A Case Study of Introductory College Chemistry Students

For decades, research has reported on the exodus of college students from science, technology, engineering, and mathematics (STEM) majors presumably due to an unsupportive culture which does not promote a sense of belonging (Hill et al., 2010; Seymour & Hewitt, 1997; Seymour & Hunter, 2019). These high attrition rates contribute to the ongoing lack of graduates for the STEM workforce (Olson & Riordan, 2012). Colleges and universities have been called to address the high attrition rates of STEM students and some have been slow to respond (Graham et al., 2013). Introductory courses are pivotal in students' decisions to persist in their major and the curriculum design of these courses contributes to this ongoing trend where students leave STEM majors (Seymour & Hunter, 2019). Traditionally, introductory undergraduate STEM courses are meant to "weed-out" students, cultivating a highly competitive environment (Gasiewski et al., 2012). For example, grading on a curve is a common practice in introductory STEM courses. This unfortunately positions students as competitors rather than collaborators when grading is based on the relative performance of their peers (Bowen & Cooper, 2022). This competitive atmosphere can lead to further social isolation. A "weed-out" focused, highly competitive, environment also contributes to the misconception that students who do well in STEM have innate abilities, also known as a fixed mindset (Seymour & Hunter, 2019). These beliefs isolate students into tiers of academic "giftedness," which creates barriers in collaborative work. Another issue to consider is the lecture environment. Typically, high enrollment, traditional lecture-style delivery is still the most common method of instruction in introductory STEM courses (Stains et al., 2018). This teaching style inevitably contributes to passive, isolated learning instead of active, collaborative learning. In a meta-analysis of 225 studies exploring student success in STEM courses, Freeman et al. (2014) found students were 1.5 times more likely to fail when active learning components were not implemented.

Graham et al. (2013) highlighted the importance of active learning and learning communities to promote STEM student persistence in their majors. Curriculum facilitating active learning and learning communities provides opportunities to engage in scientific practices and social experiences, creating a sense of belonging within the discipline. When seen as a collaborator, peers who have similar zones of proximal development can scaffold learning by serving as "more knowledgeable others" in areas of interest and expertise. Peers serving as "more knowledgeable others" are able to relate to their counterparts and provide instruction on the next steps of learning (Vygotsky, 1978; Wilson & Varma-Nelson, 2016). Students need learning spaces to engage in dialogue that is free of restrictive norms (e.g., embarrassment associated with asking questions during lectures, the pressure to know new information quickly) to actively apply new knowledge and ask questions (Roseler et al., 2018; Zoller, 1987).

A Community of Practice (CoP) framework provides an analytical lens to understand the collaborative dynamics of STEM students' engagement in STEM practices. This generates implications for curricula supporting active learning and a sense of belonging among students. Wenger et al. (2002) defined a CoP as ". . . groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (p. 4). In this study, the CoPs under investigation were groups of up to 30 students who meet on a weekly basis to engage in active learning experiences during a semester. These CoPs were comprised of smaller groups of three to four students with different levels of chemistry experience as well as students designated as peer leaders who guided the active learning experiences. These CoPs shared the mutual goal of completing an introductory-level chemistry course. Most higher education CoP studies focus on faculty experiences (Bosman & Voglewede, 2019; Drouin et al., 2014; Hakkola et al., 2021; Tomkin et al., 2019) and have revealed the innovative influence of this perspective on the collaborative improvements for instruction. Fewer studies have analyzed undergraduate students from a CoP perspective (Holley & Taylor, 2009; O'Donnell & Tobbell, 2007; Thiry & Laursen, 2011) and none of these studies examined a traditional, undergraduate classroom experience. Holley & Taylor (2009) examined the experiences of online undergraduate nursing students at a public, flagship university. While O'Donnell & Tobbell (2007) studied adult student transitions to higher education, and Thiry & Laursen (2011) investigated interactions between undergraduate researchers and their advisors at research-intensive universities. These studies surface the meaningful, peripheral participation of students integrating into STEM sociocultural practices (e.g., undergraduate research, knowledge acquisition) and how engagement in a CoP can impact student academic identity and sense of belonging. This study examined aspects of the development of a Community of Practice for undergraduate STEM students enrolled in an introductory chemistry course at a primarily undergraduate institution (PUI). PUI defined here as an institution granting 20 or fewer PhDs. Furthermore, the primary research question for this study looks at: *From students' perspective, what components of a community of practice emerged as being important when participating in an introductory chemistry course?*

Communities of Practice Theory

CoP theory incorporates three key components: mutual engagement, a joint enterprise, and a shared repertoire (Wenger, 1999). Framing through the CoP perspective provides a meaningful analytical perspective by investigating how and what is gained through participation in the community. Another theoretical perspective is “networks” which has been conceptualized as actors who are interdependent and value collaboration (Van Waes et al., 2016). Although the framing of “networks” could have been used to examine how groups collaborated in the current study, this framework does not provide robust insight into the benefits of community engagement. The CoP framework provides analytical power in curriculum design through focused constructs (mutual engagement, joint enterprise, and shared repertoire). Therefore, the CoP theory was chosen because it allows for understanding how members benefit from participation in the community.

Mutual engagement occurs when members of the CoP spend consistent time together and have common goals. In such an environment, students begin building connections and establishing a commitment toward mutual pursuits. Students begin to develop a sense of belonging in the CoP through social acceptance with others and by promoting academic motivation (Freeman et al., 2007). Typically, STEM students are committed to earning successful grades and learning required content information. The CoP needs to see value in their mutual engagement because this helps to cultivate deeper interpersonal relationships. To establish deeper commitments to their CoP, members need to see their time spent together is helping them achieve their academic goals. Deeper interpersonal commitments to the CoP are established when students have common majors and discuss content material that applies to their career paths. A sense of belonging in STEM can be cultivated when deeper connections occur in the CoP (O'Donnell & Tobbell, 2007).

A *joint enterprise* is the engagement in active learning activities and forming relationships that are valuable in obtaining mutual goals. Active learning is an impactful learning technique for introductory STEM students (Freeman et al., 2014) and can be defined as collaborative engagement in higher-level thinking (e.g., application, analysis, synthesis, evaluation, and creation) (Anderson & Krathwohl, 2001; Bloom, 1956). Active learning involves discussions that move beyond didactic discourse (Roseler et al., 2018). This learning technique may involve clarifying discrepancies in STEM knowledge, performing calculations with peers, and studying for exams together. Given that students enter introductory STEM courses with a broad range of backgrounds, the collaborative nature of the joint enterprise is important because members are near each other’s zone of proximal development and are able to closely relate to peers’ STEM knowledge proficiencies (Bruffee, 1993; Vygotsky, 1978; Wilson & Varma-Nelson, 2016).

The CoP creates a *shared repertoire* by developing collective knowledge, experiences, and resources useful for current and future experiences. Since mutual engagement in the CoP occurs on a routine basis, the shared repertoire is shaped and refined over time. Constructing time management skills and study routines is helpful for STEM students' success throughout their STEM program. STEM knowledge gained in introductory courses is incremental and can be a prerequisite to advanced courses. In this study, a collaborative component, aimed to facilitate active learning and cultivate a sense of belonging among students, was established in an introductory chemistry course and examined through a CoP framework.

Research Question

While attention has been given to the benefits of learning communities in STEM (Freeman et al., 2014; Solanki et al., 2019), little effort has been made to examine how STEM students experience a redesigned curriculum from a CoP perspective. Students' experiences in introductory courses are important because their sense of belonging affects their persistence in STEM majors (Findley-Van Nostrand & Pollenz, 2017; Rainey et al., 2018). Given the importance of developing community and a sense of belonging in STEM environments (Seymour & Hunter, 2019; Thiry et al., 2011), understanding the essential components of a CoP emerging from the student perspective is important in facilitating active engagement in science practices. Furthermore, investigations on active learning implementations at colleges and universities are often situated at primarily research institutions (Henderson et al., 2011). This study was conducted at a PUI and provides a rich qualitative case to exemplify and unearth the complexities of undergraduate student engagement in a CoP. Given the importance of this context, this investigation was led by the research question: *From students' perspective, what components of a community of practice emerged as being important when participating in an introductory chemistry course?*

Methodology

Research Design

This qualitative case study examined the CoP components which emerged for undergraduate chemistry students in a course redesigned to incorporate peer-lead, collaborative learning. Case studies are meant to examine a phenomenon in a real-life, contemporary context within a bounded time and place that examines multiple sources (e.g., interviews and classroom observations) (Yin, 2017). Additionally, case studies are grounded in a participant's lived reality, which can be told through interviews and observations in authentic contexts. Interviews and observations illuminate the processes involved in causal relationships. This case study explored student perceptions of a curriculum redesign for an introductory chemistry course at a regional, comprehensive university through the lens of CoP theory.

Research Context

The study took place during the fall 2019 semester at a PUI. The university-level student demographics at the time of the study were as follows: 12,500 total students enrolled, of which 76% of which were undergraduate, 24% were STEM majors, 60% were female, 66% were white, 11% were African American, 10% were Hispanic, 3% were Asian, and 10% were from other ethnicities. Table 1 shows a detailed description of the student demographics in the introductory chemistry course; some percentages may not add to 100% if demographic information was not reported to the university. SAS software, Version 9.4 (SAS Institute, Inc., Cary, NC) was used to find summary statistics. Data is displayed as *n* (% of *N*) for qualitative variables and the mean for quantitative variables.

Table 1

Student Socio-demographics in Chemistry 1

Factor	Descriptor	All Students *n (% of N*)*	Interviewed Students *n (% of N*)*
Class	Freshman	127 (39%)	3 (25%)
	Sophomore	102 (31%)	3 (25%)
	Junior	73 (23%)	3 (25%)
	Senior	22 (7%)	3 (25%)
Major	STEM	312 (96%)	12 (100%)
	Not STEM	12 (4%)	0 (0%)
Underrepresented Minority	Yes	78 (24%)	2 (17%)
	No	242 (55%)	10 (83%)
Sex	Female	146 (45%)	8 (67%)
	Male	178 (55%)	4 (33%)
First Generation	Yes	44 (14%)	3 (25%)
	No	280 (86%)	9 (75%)
Pell Eligible	Yes	111 (34%)	6 (50%)
	No	213 (66%)	6 (50%)

**Note.* All *N* = 324 and interviewed *N* = 12. The average participant age was 21 years. Some percentages do not add to 100% due to missing information on student demographics (ethnicity and race are self-reported with the option of not reporting).

The introductory chemistry sequence consisted of two lecture courses (General Chemistry 1 and 2), each with a separate, one-credit laboratory course. The lecture courses were redesigned to add a required, weekly 50-

minute session named “Chem Success” (CS). Due to the nature of scheduling at our institution, students enrolled in corresponding laboratory courses may or may not be in the same lecture section. Thus, to maintain a consistent cohort for examination, the CS section was added to the lecture. The implementation of CS in the General Chemistry 1 lecture course was the focus of this study. The required CS sessions consisted of 30 students which were further comprised of smaller working groups. These working groups consisted of of three to four students who engaged in active learning exercises under the guidance of peer leaders. Over time, groups changed with students withdrawing and/or being absent and some small groups merging together (seen in observations and heard in student interviews). While required participation in our study was intentional to ensure all students developed a routine for completing chemistry problems regularly with their peers, other studies examining similar designs reported on student engagement in voluntary working sessions (Chan & Bauer, 2015; Lewis, 2011; Lyon, 2008; Stanich et al., 2018).

Before implementing the CS program, the entire chemistry faculty, including the second and fourth authors, met as a group. This group was comprised of all instructors who teach general, organic, and upper-division chemistry courses. The faculty generated a “Top 10” list of topics fundamental to the course. These topics became the foundation for weekly CS worksheets and quizzes. This was done to ensure relevant topics were covered to prepare students for future chemistry courses and have faculty align their instruction to be uniform across course sections. Throughout the implementation, the chemistry faculty teaching the course met weekly to discuss course progress and content. Typically, all CS sections completed the same worksheet and quiz each week and the material was aligned with the structure and content of course exams. Quizzes were scored using a common, partial credit, point distribution. All lecture sections of the same course used a common course syllabus where CS participation, worksheet completion, and quiz scores counted for 15% of the lecture grade.

At the beginning of each semester, peer leaders engaged in an eight-hour training designed by education and chemistry faculty and pulled from published best practices (Cracolice & Deming, 2001; Varmas-Nelson & Cracolice, 2001; Woodward et al., 1993). These included exercises to allow peer leaders to identify their individual leadership style, an overview of what STEM Success “is and what it isn’t”, the goal of worksheets, and group work activities, metacognitive learning strategies, and how to address students in crisis. After the initial training session, each leader was provided a binder with information on each of these sessions for reference as well as contacts for student support services. Peer leaders helped set expectations for CS to be “working sessions” and not a time for students to ask questions about homework. They would refer students to the free tutoring made available through the chemistry department for help with homework questions. Mandatory attendance was emphasized and students were expected to work with their team members as an active part of the working group. To continue developing throughout the semester, peer leaders were required to attend lectures to refresh their content knowledge and met with faculty weekly for roughly an hour to gather feedback on the sessions and review content for the following week.

During the implementation of the CS program, traditional lectures of 90 students met face-to-face for instruction, with an additional 50-minute CS session to practice concepts taught during the lecture. Lecture students were grouped into three sessions of 30 students each, with two undergraduate peer leaders assigned per session. Students who had previously completed the general chemistry courses were invited to apply to be peer leaders and during their interviews, displayed a desire to help other students. The CS sessions consisted of undergraduate peer leaders guiding students working in small groups on worksheets. This arrangement allowed students to ask questions and clarify concepts from the lecture in a smaller group setting without faculty presence. Following the group work, students independently completed weekly quizzes. During the first CS session, students completed an interest inventory (Supplement 1) and an algebra pre-assessment (Supplement 2). The results of the algebra assessment and interest inventory were used to assemble students into working groups. Students were grouped with three to four peers who had a range of both math skill and self-reported prior experiences with the course material (low-, mid-, and highly experienced students in each group). When possible, students were also matched by similar interests such as major. In addition to using the algebra pre-assessment for grouping purposes, students scoring a 60% or lower on the algebra pre-assessment were identified and contacted by the instructor for follow-up math assistance within the first few weeks of the term.

Data Sources

Yin (2017) suggested multiple data sources build an in-depth and contextualized case about complex social contexts. Semi-structured interviews and CS classroom observations were the data sources in this study during the final months of the fall 2019 semester. The primary data source was semi-structured interviews conducted by the first author with 12 willing students. Of the 12 students interviewed, 33% were male and 67% female with 25% freshman, 25% sophomore, 25% junior, and 25% senior-level students. Students were invited to interview through their online course platform and the selection criterion was enrollment in a CS section. All chemistry students who volunteered were interviewed to share their experiences in CS. During the process of requesting informed consent, the first author informed participants their interviews would not affect their course grades. The interviews were up to 30-minutes in length and were conducted in person. The interview protocol (Supplement 3) was developed to understand a student's overall experience in CS with focused questions relating to active learning and working with peers. Below are two selected prompts that were used during the interviews.

- Tell me about a time in Chem Success that exemplifies your comfortability in your work time with group members.
- Has your time in Chem Success motivated you to visit with your professor and/or support services such as STEM coaching and/or tutoring?

Additionally, eight CS classroom observations were conducted by the first author and education faculty mentioned in the acknowledgments. The observation protocol (Supplement 4) consisted of initial procedures, guiding questions, and reflection questions. The initial procedures guided the format of the records, such as first sketching a map of the classroom and taking notes on observations, not interpretations. The guiding questions included the following:

- In what ways does the STEM Success Section (Chem Success) contribute to student engagement in active learning?
- Are students engaged in higher-order thinking (analysis, synthesis, and evaluation)?
- Are students asking the instructor questions about their work that go beyond didactic responses?

Following these questions and indicators, student behaviors and interactions were recorded as they related to active engagement in a CoP. The reflection questions were answered shortly following the observations to generate interpretations from the observations. One reflection question was, *Overall, what are your impressions of how students engaged in active learning? Explain what you saw that informs your thinking.* Five out of 12 CS sessions were observed once or twice during the final months of fall 2019. These five sessions were selected because they were led by different CS leaders, which helped the authors gain a broad sense of their pedagogical approaches.

Data Analysis

Three stages of analyses derived from Groenewald's (2004) phase strategy for explicating data were completed. For the first stage of data analysis, the research question was used to identify 'units of meaning' about the components of CoPs (mutual engagement, joint enterprise, and shared repertoire). Second, 'units of meaning' were clustered to form themes representing the answer to the research question. Finally, the themes developed were used to answer the research question. Throughout the data analysis, different sources (e.g., interviews and classroom observations) underwent triangulation to uphold the trustworthiness of the evidence to support the answers.

Researcher Roles and Trustworthiness of Data

Guided by Roulston and Shelton (2015), steps were taken to ensure researcher roles did not introduce bias and would uphold the trustworthiness of data. Researchers for this study include one chemistry faculty (author number four who taught one of the chemistry courses involved in the study), education faculty (author one) who conducted interviews and classroom observations of CS sessions, and statistics faculty (author three) who summarized quantitative student demographic data. The chemistry faculty teaching the introductory level courses provided access for education faculty to conduct observations and interview students. To avoid researcher bias among participants and confirmation bias among researchers, none of the chemistry faculty (including author number four) collected data or led the data analysis. As mentioned in the previous section, observation data sources were also analyzed to triangulate themes to form thick descriptions.

Findings

CoP constructs organize the findings to answer the proposed research question to determine what components of CoP were predominant when participating in introductory chemistry courses. The following themes centered on CoP theory (Wenger, 1999) emerged to answer the research question:

1. Mutual Engagement: Sense of comfort grew by connecting on a common struggle
2. Joint Enterprise: Engaging in active learning that involved higher-level thinking with peers who have various backgrounds
3. Shared Repertoire: Exchanging study strategies and developing routines together

During analysis of the CoP constructs, student challenges to engage in the CoP also emerged. These challenges were some students perceived the time in CS as poorly planned and students questioned their undergraduate peer leaders' chemistry knowledge. Each of these ideas is explicated below.

Mutual Engagement: Sense of Comfort Grew by Connecting on a Common Struggle

Throughout the semester, the students were focused on course grades, which motivated student mutual engagement in CS. General Chemistry 1 is a prerequisite or program requirement for many students, and satisfactory grades are needed to advance in their academic programs. Through observations during CS sessions, students often expressed chemistry is challenging and they knew upcoming exams were going to be difficult. Ten interview participants discussed the importance of working together because chemistry is challenging. This mutual sentiment helped them feel a sense of belonging instead of feeling they were the only student struggling with chemistry. One student explained, “It’s helpful just knowing that you’re not by yourself with chemistry and struggling by yourself.” Spending time together provided students opportunities to discover a common perspective which helped them feel less isolated in the chemistry course. Peer leaders and classmates were observed affirming chemistry is challenging during sessions and supporting community members by sharing strategies to complete problems.

Students’ mutual engagement also provided time for them to feel comfortable working with their peers. One student explained how a sense of camaraderie was formed in his group, which facilitated mutual engagement that extended beyond the required work they engaged in during CS: “We studied together before exams. We have each other’s numbers, so I feel like it’s [engagement in CS] built camaraderie between people at a similar level and with similar interests.” For this student, mutual engagement helped him feel comfortable meeting with other students to study for exams. Another student explained her experience of feeling shy at the beginning of the semester but becoming comfortable with talking with her peers about chemistry and other topics:

> At first, you are kind of shy when you don’t know people. But, as we started working and asking more questions, we got more comfortable with talking [to each other]. Not just about chemistry, kind of like outside stuff. And, you know, chemistry also.

These conversations included topics beyond chemistry and allowed students to build deeper interpersonal connections, which helped the student feel more comfortable about asking more questions in chemistry. Another student explained she was able to connect with her group members because they shared similar majors. She was further along in her program and appreciated the opportunity to share insight with them:

> I honestly think it was because we all have the same major. I was able to give them [information] because I’ve gone through the major and they’re new to the major and I thought that was really cool. I was able to give them insight into things that I felt were hard. Things that I enjoyed about it. So, I feel like us having that similarity was really beneficial and made us definitely click because we had things to talk about.

Mutual engagement provided time for students to build camaraderie in learning challenging chemistry content. This mutual engagement helped them participate in activities and develop resources that helped them succeed.

Joint Enterprise: Engaging in Active Learning that Involved Higher-Level Thinking with Peers who have

Various Backgrounds

Mutual engagement in CS facilitated a joint enterprise of activities and relationship building which promoted active learning of chemistry concepts and helped students achieve their academic goals. Eleven interview participants discussed engagement in components of active learning, which included collaborative engagement in higher-level thinking (e.g., application, analysis, synthesis, evaluation, and creation) (Anderson & Krathwohl, 2001; Bloom, 1956) or discussions that moved beyond didactic discourse (Roseler et al., 2018). As one student explained, “I believe Chem Success gives an opportunity to help students collaborate with each other and clarify what the lecture [covered] and the concepts we learn.” The primary learning activity was completing chemistry worksheets that required applying the chemistry content covered during the previous week with their groups. Before CS sessions began, many students were observed discussing the chemistry concepts covered in the lecture. As they completed their worksheets, students were observed referring to their lecture notes and helping each other identify pertinent information. This helped them prepare for a graded quiz completed during the last 10 minutes of the CS session.

Most peer leaders were observed beginning the CS session by presenting key concepts students would use in completing their worksheets and soliciting questions. Then they shared tips with students, such as methods for working through the problems. After the worksheets were disseminated, students took about five minutes to review the problems and then began working as a group to generate questions for discussion with their peers and peer leaders. One student explained how he worked through the worksheet with his group:

> We start working individually and if we have questions, we ask each other. Like, ‘Hey, how did you do this problem? or ‘How did you convert this to this?’ And then we checked answers at the end to see if we all did it right.

Students saw the value of reviewing problems individually for five to ten minutes before working as a group for the remaining 30 minutes before taking a quiz. They knew that applying their chemistry knowledge was an important step in developing their knowledge. This process is different from one student doing the chemistry calculations and other students copying their work. As another student explained:

> That’s part of what I like about us each trying it on our own first. Because that means we’re not just copying answers off of each other. Or like having one person write it all and then we’re all like, ‘Oh okay.’ And then copying it down.

Another student emphasized the importance of applying their chemistry knowledge in comparison to passive activities. To him, *doing* chemistry problems was the most valuable aspect of CS:

> You are actually physically engaged in doing the problems and thinking for yourself. And it's literally, pretty much, a solid 50 minutes to an hour. It's kind of like . . . I guess that you could say it forces a person to sit down and really, you know, spend some time with the material and actually think about it and focus on it. And I think that helps a lot. I think that is the biggest thing, as opposed to if it was just another extra 50 minutes of question and answer, going through lecture, practicing problems on the board . . . You actually get the sheets. You actually have to do it.

Through classroom observations, students were observed consulting with their group members and CS leaders when they did not know how to continue their worksheets during the 40 minutes of work time before taking the quiz. During interviews, students discussed the importance of members (CS leaders and peers) who had different chemistry knowledge and expertise on various chemistry concepts. One student explained the benefits of working with both CS leaders and peers:

> I think it really helps a lot. Because if you are kind of confused and there's only like two Chem Success people in there. There's generally a lot of students who understand what's going on pretty good. And I would probably say it definitely helps a lot having that peer-to-peer engagement if you are confused about something and just being able to look to your neighbor and being like, 'Hey could you explain this to me.'

Students knew it was essential to feel comfortable with their efforts to learn chemistry and they recognized their peers could help them in their chemistry learning process. They also discussed the benefits of CS leaders who had more experience with chemistry. A student explains the value of CS leaders in explaining material when needed:

> My instructors [CS Leaders], I have two instructors. They're both really good. Whenever they meet up, they basically clarify the lesson and they clarify it to the point where I definitely understand it. And if I do have any questions, they don't waste any time helping me.

Another student explained how CS leaders could sense and relate to their needs when asked what was most helpful about CS:

> Most helpful? Probably the Chem Success leaders. Like the people who are actually in there. They explain things really well and are always available to help you. They just go around and help. They can honestly kind of tell when someone is confused at this point. Like they can just read it on our faces.

The worksheets and quizzes were developed to align with the lecture content and provided opportunities for students to apply their knowledge with the support of peers with different levels of chemistry knowledge. This joint enterprise was designed to be challenging to develop their knowledge and meet academic goals. CS members with different levels of chemistry proficiency were observed supporting this development by sharing their experiences and knowledge through conversations that extended beyond didactic responses. When asked about the value of working in a group, another student commented:

> At least in chemistry knowledge, we're all at the same level. So, we all sit down and work the problems together. If they [group members] remember something from the notes or a problem that we previously worked, they are able to help me. So, I feel like relatively the same knowledge allows us to work a lot better together because there's not just someone who knows all of the information and someone who doesn't have a clue of what's going on. So, I feel like we've been able to all add something to our group.

The CoPs provided students spaces to engage in active learning and develop meaningful relationships in their pursuit of completing an introductory chemistry course.

Shared Repertoire: Students Exchanged Study Strategies and Developed Routines

Ten interview participants discussed the development of a shared repertoire (knowledge, experiences, and resources useful for other courses and experiences as undergraduates) through sharing study strategies, developing study routines, and gaining a sense of normalcy about engaging in peer tutoring. As discussed earlier, students were committed to the mutual struggle of learning chemistry, and they often had to improve their study techniques. In CS, students benefited from learning about how their peers studied. One student explained, “It [time spent in CS] just kind of helps you work with other students. You get to know other students and their methods of studying that could probably help you in the future for studying.” This student perceived her engagement in CS as an opportunity to learn about different study methods that could be helpful in her current and future courses. Another student shared how CS connected her with new students and exposed her to different study methods, “So it [CS] allows me to work with other people in chem and kind of get notes and their take on how to do things and everything.” Learning how other students studied provided students with strategies that could help them in their broader academic goals.

Students also developed study routines because of their mutual engagement in CS. Students described studying the material weekly, as opposed to studying immediately before an exam. As one student explained:

> Because if I didn't have the chem success there, I don't think I would have . . . I would have definitely procrastinated a lot more like there would have been a solid gap of like a week that I would just have went and didn't do any kind of chemistry whatsoever.

Students discussed alignment between their weekly homework assignments from lectures, CS worksheets, and CS quizzes. The alignment between these materials provided them with an opportunity to develop study routines. CS activities and group work helped guide students to focus on relevant content to study. One student explained he used his worksheets and quizzes to study for exams, "Whenever I'm studying for my exams, I usually pull out all the documents that I've studied so that it's usually like the quizzes from my class and like the [CS] worksheets and quizzes." Also, several students mentioned questions on worksheets and quizzes were structured similarly to the exam questions. Here another student explained, "The thing that stands out the most about CS is how it's structured. It's like we get to see those problems and concepts as we would see them on an exam." Another student discussed how he discovered the necessity of studying chemistry material weekly due to the curricular alignment between the lecture and homework, which helped him prepare for CS:

> One of the things that I figured out really quickly in the first three weeks was like, okay if I got to go to lecture and then our homework assignments are generally due on a Friday. And in this homework assignment . . . The material in the homework generally covers the material that we got in the lecture and the Chem Success. So, what I'll do is every Tuesday is I'll do the homework. And that way, when I went to the Chem Success it was fresh in my mind.

Having material "fresh" helped him actively engage in the joint enterprise of CS. Implementing an incremental routine also helped students feel comfortable with the material. As mentioned earlier, performing well in chemistry was a common struggle for many students. Developing study routines helped students feel comfortable with the material by practicing on an iterative basis. Another student explained her experience in CS:

> Definitely coming into the school year, probably chemistry was the course where I think that I was the most nervous. And I would probably say that kind of having that extra block in the week definitely kept me engaged with it. So, it was nice to go through the lecture. You know, I had mine in the middle of the week, so I thought that was like the perfect time. You know, get some review at the lecture. Do my homework, and then, I came to the Chem Success and I was like, 'Oh I kind of had forgotten about chemistry. I hadn't

> really done anything for a while.' It just hits you right in the face and just gets you right back in there and keeps you with the program.

Iterative study routines were essential for deep engagement in CS, which will be helpful for students throughout their collegiate experience.

Finally, students were encouraged by CS peer leaders to visit chemistry tutors for additional assistance. Students may feel reluctant to utilize tutoring because it is optional support that not all students utilize. However, tutoring is helpful for effectively learning chemistry material, and CS normalized student engagement in this service. One student explained her increased comfortability with visiting a chemistry tutor because she recognized her tutor, who did not make her feel awkward engaging in tutoring:

> I was able to go to a tutor section and then the tutor that was there during that time slot when she left [her CS leader] came in. So, it was nice to see a familiar face as well, helping me. Because he also knew where I was at. So, it just made me feel not as embarrassed honestly. It made me feel more open and welcomed for me to go and breach those resources and I didn't just feel like a dumb student.

Some students do not know about tutoring and need it explained to them. After this explanation, students can see the value of the service. One student described that his CS leader helped him understand tutoring, which helped him see the value of the service for the laboratory component of his coursework:

> Yeah, they've encouraged us and told us that this is our available times. So I have gone tutoring a couple of times. Not for chemistry homework, but for my labs because those are kind of complicated sometimes. So, him describing and explaining that resource has definitely helped.

This shared repertoire helped deepen students' mutual engagement and joint enterprise as they collaborated in CS. Students exchanged their study strategies and developed study routines, while CS leaders helped normalize support services such as tutoring. Students suggested that this shared repertoire was helpful in other courses and may be helpful in their futures as students.

Challenges to Engaging in the Community of Practice

As the three components of a CoP (mutual engagement, joint enterprise, and shared repertoire) were analyzed, challenges to engaging in the CoP by students emerged. The mutual engagement of students was affected by how valuable they perceived their time in CS, which may have affected their engagement in the CoP joint enterprise and development of shared repertoire. Three interview participants did not believe the course time in CS was planned well. One student explained, “We usually finish up by about 20 minutes in, but we have to wait for around 12:40 to start taking the quiz, so we just wait around.” Students who did not see their time as being well spent may not have been fully engaged and benefited from the CoP. To address some of these concerns, changes to future semesters included the implementation of a CS workbook. Weekly worksheets were combined into a single workbook with additional problems to help fill the time for groups finishing early.

Another challenge that emerged was students questioning the peer leaders’ knowledge of chemistry. This was discussed by three interview participants who engaged in three of the 12 CS sections. This affected their trust in CS leaders’ guidance in their chemistry work. In some cases, students mentioned CS leaders did not know how to answer questions. One student explained she questioned the process for solving a problem and the CS leader was not specific in explaining the rationale for each step of the calculation:

> Sometimes they confused me with the way they teach it where they just tell us that we’re supposed to do it this way. But like, I am a why type of person, so I kind of ask questions. Like why? And sometimes they don’t explain really well like, why we are doing this or each step to get to your answer. They’re kind of just like you have to do this. You have to do this and then it should give you your answer.

Since this student was a “why” person, she may not have connected with the CS leaders because her questions were not answered. Later in the interview, she described how these interactions with CS leaders prevented her from trusting CS leader’s guidance. In other cases, students discussed asking the CS leader questions, which led to more confusion. Here, a student explained:

> In my group we tend to work on the problems individually and then compare our answers. Or if one of us is having a problem, which often happens, we’ll go to each other to bounce ideas off of each other on how to do it. And about once a session, my group will get really stumped and we’ll raise our hand and it’s usually the same guy who comes over to help us. I think his name is Jim [pseudonym for CS leader]. He does his best and very clearly wants to help us, but there’s a lot of confusion.

Students who become more confused after asking their CS leader for clarification led them to question the CS leader’s chemistry knowledge. These two challenges may have affected students’ mutual engagement and joint enterprise.

Discussion

STEM faculty have been called to implement curricula to help STEM students persist in their majors by facilitating learning communities (Graham et al., 2013). This study provides a rich case study of student engagement in a chemistry course redesigned to facilitate active learning and develop a sense of belonging. Undergraduate chemistry students were studied using the CoP framework that investigates students' mutual engagement, joint enterprise, and shared repertoire. CoPs are groups of people who spend time with each other on a consistent basis to address a common concern and shared goals (Wenger et al., 2002). In this study, class sessions of up to 30 students, divided into small groups of three to four and peer leaders, met on a weekly basis to engage in active learning experiences during a semester. These CoPs shared the mutual goal of completing an introductory-level chemistry course. Research has shown CoP is a powerful lens to learn about community participation, yet most have examined faculty experiences (Bosman & Voglewede, 2019; Drouin et al., 2014; Hakkola et al., 2021; Tomkin et al., 2019). Examining student perspectives through a CoP lens has led to possible curricular lessons useful for STEM faculty departments. This section is organized by the following salient themes which highlight the value of curriculum structured to support active learning and a sense of belonging: The CoP was a meaningful space to develop a sense of belonging in STEM and the CoP was a meaningful space to actively engage in science practices.

The CoP was a Meaningful Space to Develop a Sense of Belonging

Students built a meaningful sense of belonging extending beyond earning grades that may have increased their sense of belonging in the chemistry community. “Fit” is an important factor in developing a sense of belonging (Hoffman et al., 2002) and can be defined as how an individual perceives their values and beliefs aligning with others within a domain (Hagerty & Patusky, 1995). Through mutual engagement, students in the current study related to each other in the opinion that chemistry is complicated. STEM students have cited difficulty in understanding STEM-related concepts as a reason for switching their major or leaving college for decades (Seymour & Hewitt, 1997; Seymour & Hunter, 2019). In this study, students openly shared this disposition and supported each other by acknowledging a collective struggle. This sharing helped students see their belonging in the STEM domain. Connecting on a common struggle and developing a sense of belonging takes a step toward addressing the competitive and isolating culture that often is a part of introductory level STEM courses (Bowen & Cooper, 2022; Gasiewski et al., 2012; Seymour & Hunter, 2019). The CoP provided students time and meaningful activities to develop collaborative relationships helping them successfully complete an introductory chemistry course.

The CoP Facilitated Active Engagement

Most students engaged in higher-level thinking actively applied concepts learned in lectures on a routine basis (Anderson & Krathwohl, 2001; Bloom, 1956). Working individually on problems followed by group discussions was a common technique used and highly valued among students. Active learning has been shown to be an impactful technique in introductory STEM courses (Freeman et al., 2014). Active learning was supported in CS partly because the learning space was designed to facilitate a sense of belonging among students. CoPs provided students spaces to ask questions with peers who had multiple levels of chemistry understanding and avoid feeling embarrassed. Students collaborated with peers within their zone of proximal development who could serve as the "more knowledgeable others" (Vygotsky, 1978). Students also felt comfortable asking questions and engaging in additional services (e.g., tutoring) to continue their learning. This curriculum is atypical (Stains et al., 2018), but is recommended for faculty engaging in course redesign to facilitate collaborative learning space, which Graham et al. (2013) highlighted as being important for STEM students to persist in their majors.

Implications for Chemistry Curricula at Primary Undergraduate Institutions

There are several implications for STEM faculty when considering approaches to learning in large undergraduate introductory STEM courses. Introductory chemistry courses at PUIs may benefit from implementing a curriculum similar to the course design of this study. This may help students develop their sense of belonging in STEM and engage in active learning. STEM faculty engaged in course redesign may consider lessons learned from the challenges emerging from this study. Students expressed both satisfaction and discontent with the expectation they are required to meet weekly and actively engaged in chemistry calculations. Instructors may consider discussing the roles of different members, especially the role of the peer leader. In this study, course designers expected peer leaders to connect to a student's chemistry proficiency and guide them to the next level of understanding as "more knowledgeable others" (Vygotsky, 1978). They were not expected to explain different methods of solving chemistry problems. Findings show confusion in these role boundaries affected students' thoughts of motivation for engaging in the CoP. Given these results, instructors should introduce and remind students of role expectations. This study was limited to using undergraduate students as more knowledgeable others. In this role, undergraduate students may not have a breadth of knowledge to describe ideas from multiple perspectives.

Implications for Scholarship

Most studies in higher education adopting a CoP theory focused on faculty experiences (Bosman & Voglewede, 2019; Drouin et al., 2014; Hakkola et al., 2021; Tomkin et al., 2019). However, studies have shown insightful findings when analyzing student experiences through this lens (Holley & Taylor, 2009; O'Donnell & Tobbell, 2007; Thiry & Laursen, 2011). More studies could utilize this theory to understand students as developing practitioners of their domain. In the current study, this analytical lens led to empowering findings showing student engagement in the practices of their domain. Also, future research might examine how engaging in a CoP affects the identity of undergraduate students at PUIs. Examining constructs of identity may further understanding of how students see themselves (Wenger, 1999). Another research focus might examine educational infrastructure components (e.g., curriculum materials, instructional routines, roles, and positions focused on pedagogical support) that are meaningful in implementing a CoP curriculum (Penuel, 2019).

Limitations

This study has some limitations that must be addressed. First, the data analysis did not examine specific social identities of students (e.g., gender, race/ethnicity, first-generation). Rather, this study focused on the broader experiences of students. As a result, reporting on specific social identities and demographics was not accomplished. Second, the case study research design limits the generalization of results to institutions with similar demographics, as discussed in the methodology section. Finally, this study was conducted at a PUI in the southeast region of the United States. Implications of the study should be understood through the lens of this context. While we are not making causal relationships between elements of CoP and student mastery of subject material, we have observed positive interactions between groups of students with shared experiences and interests. Further research in this area is encouraged to explore potential causal relationships. Third, the timing of the data collection was near the end of the semester. Collecting data throughout the semester would have shown how CoP components evolved which is important when considering the development of learning communities. Future research should consider longitudinal data when examining undergraduate students' perspectives of CoP components.

Conclusion

Given the urgency and ongoing call for college faculty and administration to structure introductory-level STEM courses to facilitate collaborative work, this study provides a rich case study of students in an introductory chemistry course. A better understanding of introductory STEM course implementation was explored through the research question, *From students' perspective, what components of a community of practice emerged as being* *important when participating in an introductory chemistry course?* In this study, students were required to meet weekly and complete chemistry problems through required weekly sessions led by undergraduate peer leaders. Findings show participant engagement created opportunities for collaboration beyond the required weekly sessions, including forming study groups and seeking assistance from chemistry tutors. Participants also shared study techniques based on a mutual understanding that effective learning required routine practice. These findings suggest students developed a sense of belonging and engaged in active learning, which are two techniques to support and encourage persistence in STEM majors (Freeman et al., 2014; Graham et al., 2013).

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