What makes Communities of Practice Persist? Lessons from Anatomy and Physiology Instructors Communities of Practice

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Abstract

While there has been a recent focus on developing programs to support educational research by community college anatomy and physiology instructors, there is not yet an established long-term community of practice (CoPs) in this particular area. Studies of long-term CoPs, particularly in STEM education, are few and far between. This study examines College in the Schools (CIS), a long-term community of practice for high school anatomy and physiology (A&P) educators in Minnesota and Wisconsin. In addition, this study highlights the factors that attract high school A&P teachers to CIS and the possibility of creating a similar CoP for community college (CC) A&P instructors focused on educational research. It was discovered that despite their varying reasons for joining, members of CIS and CC instructors tend to participate in CoPs similarly. As a result, A&P instructors from CC who are interested in educational research could benefit from a CoP structure similar to CIS over a longer period of time.
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Introduction

As higher education institutions continue to face issues with student learning, grit, and graduation in science, technology, engineering, and mathematics (STEM) programs, STEM educators in post-secondary institutions are being called upon to adopt evidence-based instructional practices (EBIPs) in order to improve student outcomes (Kezar et al., 2017; Ma et al., 2019). However, more than mere encouragement is needed to facilitate instructional change. Faculty encounter both internal and external barriers to implementing EBIPs, including limited access to professional development opportunities, little time to implement changes to teaching, and conflicting personal beliefs about teaching and learning (Andrews & Lemons, 2015; Edwards et al., 2015; Hyson et al., 2021; Ma et al., 2019; Schinske et al., 2017; Seithers et al., 2020).

Theoretical Framework

Lave and Wenger (1991) defined Communities of Practice (CoP) as "a set of relations among persons, activity, and world, over time and in relation with other tangential and overlapping communities of practice" (p. 98). The concept originated in Lave and Wenger's 1991 book *Situated Learning* and is further elaborated on by Wenger in a 1998 book entitled *Communities of Practice: Learning, Meaning, and Identity*. Researchers have based the theory of situated learning on studies of apprenticeship learning models focusing on practice in relationships. In the apprenticeship model, all members teach internal norms and discourses through organic participation. The emphasis is on learning through practice. As newcomers enter a community, they reach a point of legitimate peripheral participation where all participants learn and engage through a community of practice. They observe, identify, and emulate standards modeled by masters or old-timers. Within the CoP model, old-timers are the more experienced peers facilitating newcomers' learning through example and interaction. At the same time, the leaders are learning from the fresh perspectives and experiences new members bring to the community.

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A typical example of situated learning theory and communities of practice is the Alcoholics Anonymous program. According to Lave and Wenger (1991), more experienced members in that program provide "counter exemplary stories" in response to newcomers' initial stories without directly criticizing or correcting them (p. 106). Instead, the experienced members continue telling their stories using the tropes and techniques familiar to that community. As new members gain appropriate storytelling skills, they are validated for them, eventually developing into exemplary storytellers. Experienced members do not explain storytelling to newcomers by sitting down with them. Instead, newcomers learn by listening and telling stories themselves.

Similarly, situated learning theory is central to the student-teaching model in teacher education programs. Pre-service K-12 teachers learn through practice and mentorship in supervised practicum and clinical student-teaching placements. Given the argument that teachers learn by doing, we extend the situated learning theory and CoPs to investigate teacher practices in higher education.

Communities of Practice in STEM Education

For this paper, we applied Barab and colleagues' definition of a community of practice (2002) as a network of individuals focused on a common practice who share experiences, beliefs, values, history, and knowledge. CoPs focused on STEM education reform provide interested faculty with the support and engagement necessary to adopt EBIPs or conduct educational research despite institutional barriers (Kezar et al., 2017; Ma et al., 2019; Nadelson, 2016; Olitsky, 2015; Townley, 2020). Unlike the K-12 pre-service teachers who learn through a structured and rigorous apprenticeship, instructors in higher education rarely have direct support in pedagogical practices. Specific challenges are associated with building and maintaining long-term CoPs in higher education. Through their study of four long-term STEM education research CoPs, Bernstein-Sierra and Kezar (2017) have identified five central challenges and solutions for creating sustainable, long-term Biology Education Research (BER) CoPs, (1) funding, (2) leadership, (3) staleness, (4) perceived threats of legitimacy, and, (5) maintaining integrity.

The majority of these CoPs began with short-term National Science Foundation (NSF) grants as a funding source, which made it challenging to hire and retain permanent staff, recruit new members, develop and train new leaders, hold face-to-face events, or continue developing new materials after the grant was complete (Bernstein-Sierra & Kezar, 2017). The original leaders of these CoPs were charismatic people hand-picked by the primary investigator to embody the mission of the CoP; however, these leaders tended to leave a void when they stepped down (Bernstein-Sierra & Kezar, 2017). As these CoPs continued to grow, the original learning parameters were at risk of becoming stale through repetition over time and reliance on similar ideas (Bernstein-Sierra & Kezar, 2017). Bernstein-Sierra and Kezar (2017) discussed that STEM education reform CoPs often lack acceptance from the broader academic community due to their focus on teaching and pedagogy rather than biology, which is more rewarded in academia. To prove their legitimacy, the CoPs in this study validated their practices through educational research (Bernstein-Sierra & Kezar, 2017). Finally, the needs of the academic community, funders, and STEM fields may diverge from those of the CoP, therefore testing the integrity of the CoPs in their focus on specific learning parameters (Bernstein-Sierra & Kezar, 2017).

Long-Term Support for CoPs

For these CoPs to persist over the long term, they established sustainable funding models and hired professionalized staff rather than relying primarily on volunteers (Gehrke & Kezar, 2018; Kezar & Gehrke, 2017; Kezar et al., 2017). They also created flexible leadership development and succession plans and encouraged members to step into leadership positions (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017). The long-term CoPs provided transparent goals and clear mission statements and integrated new opportunities with scheduled and predictable opportunities for participation (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017). The communities also adapted the CoPs to participants' needs by building checks and balances into the flexible organizational structure and allowing for self-reflection and criticism within the community (Bernstein-Sierra & Kezar, 2017).

To further support long-term STEM education reform CoPs, it is vital to consider the strong learning abilities of STEM faculty and identify ways of supporting them in the shift between research norms, methods, and practices within STEM fields and education research and emphasize that, while different, both types of research are rigorous (Nadelson, 2016). Generally speaking, faculty engagement in and design of CoPs results in learning and improving pedagogical practices, developing leadership skills, and increased networking among educators (Gehrke & Kezar, 2018). Members often consult with each other in peer-learning or brainstorming settings about teaching methods, problems in their classroom, and so on and these consultations often lead to more formal mentoring relationships (Kezar et al., 2017).

We hypothesize that the importance of personal interactions also relates to the fact that these are distance communities of practice. Typically, CoPs have regular interactions as part of an organization. Instead, individuals in STEM communities often find themselves part of a larger enterprise where their engaged reforms may receive only some support from colleagues. As a result, having colleagues to learn from, get advice from, and be mentored by was extremely important because they needed help to get this in their local departments and institutions (Kezar et al., 20107). Members of the CoP may benefit from deliberately developed public

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and private community spaces where they can learn from each other and share experiences that they do not have the opportunity to share within their departments (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

Several projects within the Biology Education Research (BER) space, including the Community College Anatomy and Physiology Education Research Project (CAPER) and the Community College Biology Instructor Network to Support Inquiry Into Teaching and Education Scholarship (CC Bio INSITES), are working to create CoPs with a culture of mutual learning and mentorship, while also encouraging engagement in BER. Connecting project participants, particularly instructors in community colleges and college-level high school environments, to long-term BER communities of practice could make these projects more sustainable. To that point, this study analyzes how two groups of anatomy and physiology educators participate in long-term communities of practice to answer the following questions:

1. **How do College in the Schools (CIS) and Community College Anatomy and Physiology Education Research (CAPER) instructors describe their participation in communities of practice?**
2. **How could CIS serve as a model for a long-term CAPER community of practice?**

The overarching goal of this study is to better envision how to create a long-term CoP for CC A&P instructors engaging in EBIPs and conducting educational research using the CIS CoP as a model.

College in the Schools (CIS)

The CIS program is a dual-enrollment program that provides college credits through the University of Minnesota to students taking the course in their home high school. High school teachers teach CIS courses classified as teaching specialists in both public and private schools across Minnesota and Wisconsin (Jensen et al., 2013). This program only accepts licensed high school teachers as instructors, who must complete an application process to participate (Jensen et al., 2013). The instructors foster an environment of active learning by designing a student-centered course (Jensen et al., 2013). The requirements for teaching the CIS Anatomy and Physiology course include three professional development sessions per year, the weekly use of cooperative quizzes, and inquiry-based instructional methods. Over the past decade, CIS has formed its own CoP, including an active listserv and open discussion during professional development days. In addition, CIS instructors attend workshops focused on EBIPs and how to implement them in the classroom and science content before and during the academic school year.

Refinement and Expansion of the Community College Anatomy and Physiology Education Research Program (CAPER)

Community college (CC) instructors are essential in education in the United States, teaching 50% of Latinx and Indigenous students and 40% of Black and Asian students at post-secondary levels (Twombly & Townsend, 2008). CC A&P instructors often teach people preparing for nursing or other health professions programs. However, CC instructors often need more access to professional development or support for engaging in active learning and performing educational research (Edwards et al., 2015; Flynn et al., 2017; Parker et al., 2016).

The current CAPER program (IUSE Award #2111119) is a multi-layered program focused on researching the efficacy of EBIPs in Community College (CC) Anatomy and Physiology (A&P) Classrooms. It is a continuation of the previous CAPER program (IUSE Award #1829157) (see https://hapsblog.org/2021/10/15/caper-is-back/ for an explanation of names). CC A&P was selected to join the program after an application process that assessed familiarity with active learning and the diversity of the students at their institutions. Most CAPER participants are recruited through the Human Anatomy and Physiology Society (HAPS) and often indicate membership in HAPS during their interviews. Through the program, CAPER participants attend two semester-long courses on pedagogy and educational research methods and design and implement classroom research projects to evaluate the impacts of EBIPs on student success and classroom engagement. The program's overarching goal is to expose CC A&P instructors to EBIPs and encourage the adoption of one or more of the EBIPs in their classrooms. The program integrates the EBIPs into the participants' coursework and provides them with didactic sessions on the history and structure of the EBIPs. CC A&P instructors also evaluate the effectiveness of their EBIPs, fostering a culture of educational research.

CIS and CAPER encourage using EBIPs in the Classroom to teach Anatomy and Physiology

Additionally, both programs provide instructor support for understanding the history and usefulness of various EBIPs and comradery to troubleshoot their implementation. The two programs differ in three main ways:

1. **High school students use CIS, while community college instructors who teach learners from various age groups use CAPER.**
2. **Unlike CIS, CAPER includes educational research as a component.**
3. **CAPER has a relatively short-term CoP, a five-year NSF-funded program, while CIS does not rely on external funding.**

This study highlights the importance of a CoP for community college faculty using a long-term CoP for high school anatomy and physiology (A&P) educators (CIS) as its model.

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It also highlights the factors that attract high school A&P teachers to CIS and the possibility of creating a similar CoP for community college (CC) A&P instructors focused on educational research. Long-term communities of practice for STEM at the community college level need to be better documented and can provide a wealth of knowledge sharing and community for those faculty.

Methods

This comparative study draws together interview data from two projects approved by the University of Minnesota Institutional Review Board: STUDY00012877 and STUDY00011020. All participants willingly agreed to participate after receiving sufficient information about the study's purpose, procedures, potential risks, benefits, and other relevant details, giving informed consent.

Participants and Sampling

The data for this study includes qualitative interviews with two groups of A&P instructors, those from CIS and CAPER. We used a random number generator to randomly select seven CIS instructors from the group of approximately twenty-five educators. We interviewed all twelve participants in the CAPER study and documented their anonymized names in Table 1.

Pseudonym	Program
Nina	CIS
Jason	CIS
Lowery	CIS
Sandy	CIS
Marj	CIS
Allie	CIS
Jeremy	CIS
Tom Smith	CAPER
Kim	CAPER
Esry	CAPER
DJ Nemzer	CAPER
Borealis	CAPER
Yara	CAPER
Bulldog	CAPER
Wheeler	CAPER
Charles Darwin	CAPER
Heather	CAPER
Monica	CAPER
Professor Humerus	CAPER

Table 1. *Anonymized names of study participants.*

Data Collection

In June 2021, we interviewed seven CIS instructors via Zoom for one hour each, and in September 2021, we conducted one-hour Zoom interviews with the twelve CAPER instructors (Figure 1.). We recorded and transcribed all interviews using Otter.ai (https://otter.ai/).

CIS and CAPER instructors use significantly different interview protocols due to differences in their research questions. The CIS interviews aimed to answer whether educators can use guided inquiry and small group learning in the classroom effectively with the help of a long-term professional development program. Therefore, in addition to questions from Luft and Roehrig's (2007) Teacher Beliefs Interview, the CIS interview protocol included specific questions about aspects of CIS and instructors' experiences in the program. The CAPER interview protocol had a broader focus on teacher beliefs (Luft & Roehrig, 2007), self-efficacy (Manduca et al., 2017), and pedagogical discontentment (Southerland et al., 2011). Both interview protocols are included in Appendices 1 and 2.

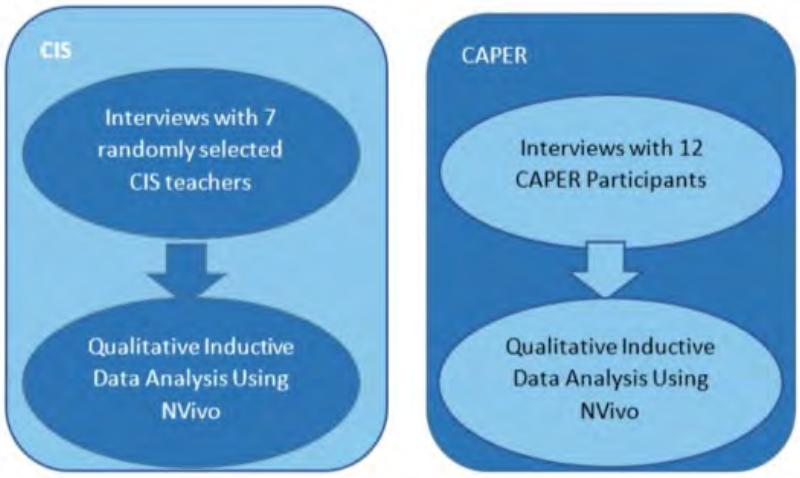

Figure 1. *Data collection and analysis.*

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Data Analysis

One of the authors (ARH) conducted qualitative open coding to identify initial themes across several interviews (Miles et al., 2014). Then, she conducted selective coding to analyze the data against the initial themes and refine these themes to better represent the data (Corbin & Strauss, 1990; Miles et al., 2014). At that point, ARH read literature on communities of practice to identify how the findings might blend with or diverge from the CoP literature. Finally, she did a separate round of open coding using Excel without reviewing previous codes to verify the themes and findings against her original coding. The codebook (Appendix 3) further explains the final themes and include isolation driving instructors towards communities of practice, collegiality within institutions leading to less active membership in communities of practice, the impacts of communities of practice on teaching, collaboration, and knowledge sharing in CoPs, and positive and negative aspects of solid leadership in CoPs. To add another layer of trustworthiness, the researchers asked MD and participants from CIS and CAPER to read and edit the article as a form of member checking (Guba, 1981; Schwandt et al., 2007).

Trustworthiness

Guba (1981) and Schwandt, Lincoln, and Guba (2007) set out four overarching criteria for trustworthiness in qualitative work: credibility, transferability, dependability, and confirmability. Credibility can be established in several ways, including research using multiple data collection forms, having multiple people code the data, member checking, and including negative cases in the study (Guba, 1981; Schwandt et al., 2007). While only one researcher coded the data for this study, ARH attempted to increase the credibility of her findings by re-coding the data four months after the initial coding process to verify her findings. She included counterexamples of her findings to show the degree to which the data represents all participants. In addition, she had the MD and study participants review the article and mark any areas in which the researcher's interpretation diverged from the participants' experiences as a form of member checking before finalizing the manuscript.

To fulfill the requirements of transferability, the researcher has provided detailed descriptions of CIS and CAPER to provide readers with a clear idea of whether or not the findings of this study may transfer to CoPs that they are involved with (Guba, 1981; Schwandt et al., 2007). She has also clearly described the interview and analysis methods used to collect the data, providing the readers with the resources necessary to conduct a similar study to confirm the findings (Guba, 1981; Schwandt et al., 2007). Regarding dependability, she had the opportunity to conduct interviews with CIS and CAPER participants and identify how their experiences are similar or different.

Results

This section describes the findings of this study by theme, divided into CIS and CAPER sections, with a comparison of the two at the end of each theme. The themes include isolation driving instructors towards communities of practice, collegiality within institutions leading to less active membership in communities of practice, the impacts of communities of practice on teaching, collaboration, and knowledge sharing in CoPs, and positive and negative aspects of solid leadership in CoPs.

Isolation Leads Instructors to Find Communities of Practice Outside of Institutions

CIS and CAPER instructors have unique difficulties finding space for professional development and growth as educators within their institutions. CIS instructors are distinct from other A&P instructors in that they are licensed high school educators who may or may not have advanced degrees. They are teaching in high schools where they may be the only educators teaching A&P. Generally speaking, CAPER instructors work in community college settings where time, institutional support, and funding often limit their opportunities for professional development and educational research (Andrews & Lemons, 2015; Edwards et al., 2015). While they may have colleagues also teaching A&P, they may not support integrating educational research or active learning into their teaching practice (Andrews & Lemons, 2015; Edwards et al., 2015).

CIS Instructors are the Only Teachers of Anatomy and Physiology at Secondary Schools

As discussed previously, CIS instructors are teaching college-level courses in high school. They are often the only A&P instructors at the school and cope with the demands of the CIS program and struggles specific to teaching A&P in isolation. Therefore, CIS A&P instructors often turn to each other for support. As Nina described:

> ***"So one of the things I will just say is working with 30 other high school teachers… During the school year, if I am thinking I'm gonna start this new unit, I can just jump on and send an email to everybody in our group and say, "I want to start teaching this topic. Does anybody have any suggestions?" Alternatively, "I cannot find this POGIL we all wrote four years ago on vaccinations. Does anybody have it?" And, you know, within half an hour, three people have written back, "Here is the link, here it is." It is wonderful to have that collegiality. Four people are in my science department…but only one other teaches life science. So I just don't have a lot of other people as resources. College in the schools has given me a huge pool of like-minded educators."***

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Nina and several other CIS instructors discussed how they interact throughout the school year and draw on each other's experiences and materials to address classroom issues or develop lesson plans.

The Human Anatomy and Physiology Society (HAPS) Provides a Sense of Community for CAPER Instructors who Aspire to Improve as Educators and Feel Isolated

Several researchers found that STEM instructors who hope to grow as educators and researchers in CC environments are often limited by their work environments (Andrews & Lemons, 2015; Edwards et al., 2015). While this is not true for all instructors participating in CAPER, two instructors precisely pinpointed how they felt limited by their colleagues and turned to HAPS as a CoP. Charles Darwin described his experiences with his department.

> ***"You know, the administration is very supportive. I've got administrative support. I get pushback from colleagues. I think they are the biggest downers… They get threatened by people who are showing success and trying to do things differently because they feel it directly makes them look bad as an instructor. So they don't want you to do it. Because it makes them look bad. So I think fighting back on that, and just being like, 'Listen, you've got your classroom. Do what you do in your room and run your course the way that you're going to run it and respect my ability to do the same thing. I won't pass judgment on you, don't pass judgment on me. And we'll see what happens.' If there was a hurdle, I would say that's the hurdle."***

He described his membership in HAPS as a group of like-minded individuals who are not threatened by pursuing opportunities for growth as educators.

> ***"HAPS has really been my support system for going in and looking at how can we engage students differently. Where else can you get into a conversation with Mark Nielsen and some of the other textbook authors on current teaching trends, that directly affect how they're gonna write their textbooks? I think there's such power in looking at what other people are doing and knowing that you're not alone and you've got a network of professionals teaching the same thing, that you are having the same struggles, and then being able to sit down and say, "Okay, what are we going to do about it?" and not be threatened by the new ideas?"***

Wheeler similarly described HAPS as her professional community that makes up for a lack of collaboration in her local space.

> ***"Yeah, HAPS is definitely my professional community. And I feel a connection to those humans that is far beyond colleagues. I definitely… we talk about it all the time in HAPS. We talk about each other like family, and it feels that way. I feel like I have mentors all over the country, all over the world, because of my relationship with HAPS. And I give a lot to the organization. And I know that that's a big part of why I feel as connected as I do. But I also feel like I… you know, most people who we connect in are… just feel that same like, "Wow, this is a really supportive, amazing group." My local colleagues are more conservative and traditional. They have learned to not try to tell me I can't do something. Nobody tells me, "Oh, you shouldn't do that." But they definitely go "Dude, what are you doing now?" There's not an "Oh, I am interested in that. Let's brainstorm. Let's work together." You know, there isn't that kind of collaboration in my local space. But yeah, the HAPS scene is just pure golden."***

Wheeler and Charles Darwin have found the supportive learning environment they need through HAPS.

CIS and CAPER Instructors and Isolation

While the causes of the isolation experienced by CIS and CAPER instructors differ, they seem to find solidarity in similar remote CoPs. The CIS instructors, as the only A&P instructors in their schools, have created a network of peer learning and sharing among themselves to share information, lesson plans, and materials through email. CAPER instructors experiencing isolation within their institutions due to a lack of support in their pursuits of active learning and educational research engage with the HAPS community online and through in-person conferences.

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CAPER Instructors Who Experience Collegiality within Educational Institutions may be Less Connected to External CoPs

Several CAPER instructors described collegial teaching and learning environments within their institutions. For instance, Bulldog described how his previous role as a college professional development fellow encouraged the development of an institutional CoP.

> ***"I was actually a professional development fellow at my college for a while. I had all the faculty getting together during brown lunches where we had everyone from chemistry, physics, biology, and health sciences in the same room sharing. So we had this little community of scholars, we're learning about the limitations of each other's disciplines, and how we could kind of look at how we teach that particular part, like A&P, when you get into partial pressures, that's math. And students immediately shut down, and the math help us a lot with little signals on how they would teach that type of stuff. So I miss my own colleagues in a way when we were getting together. And now we've kind of lost that component because we can't fund that [professional development fellow] position anymore. So mostly, it's just interacting with my peers."***

When describing his membership in HAPS, Bulldog defined himself as a "lurker type" who used to be more active but has begun to engage more with high school resources and educators since they "structure stuff much better than college people do."

Yara also described finding her colleagues within the college and school to be particularly helpful for her growth as an A&P instructor.

> ***"My colleagues. We have amazing people in our department and within our college and school, and I've been so lucky from day one that they just kind of took me under their wing. As an adjunct, it was very isolating. It was extremely isolating. I had no idea what I was doing. But my colleagues here have been beyond supportive… Just this stuff that takes so much time that you don't even have time to prepare your course or think about pedagogy. These people have supported and allowed me to grow so much as an instructor. So that's a huge resource. "Hey, I have this student who behaved this way." Snap a picture of an email from a student, "Hey, what do I do here?" We have a group text message just for biology. We have a group text message with faculty from different departments. So much support from colleagues is a huge one."***

Similarly to Bulldog, Yara talked about communication networks within the department and also between different departments. She mentioned that she has yet to find a CoP outside her institution.

As a counterpoint, Borealis tended to turn to colleagues when he has questions about teaching or runs into issues with students.

> ***"Generally, colleagues that have been here before, done this before, colleagues that do this better than I do it. I think we all have our strengths and weaknesses, too."***

In addition to turning to colleagues to address questions, Borealis is an active member of HAPS and finds motivation to keep trying new things by attending HAPS conferences.

> ***"The people in HAPS, I think, are the special sauce for it. It's has benefited from amazing leadership for a very long time, and people who want to really advance HAPS…When I come back from HAPS, I'm like 'This is great. I have all these ideas.' So it's really a very useful thing."***

Borealis' experiences working with his colleagues and participating actively in HAPS illustrate that some people like Bulldog and Yara find their colleagues supportive and do not need to look beyond their institutions. Other people engage with their colleagues and CoPs simultaneously. The varying levels of participation in HAPS described by Bulldog and Borealis also indicate that HAPS has a flexible membership model welcoming different types of participants (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

CAPER and CIS Instructors and Collegiality Within the Institution

While CAPER participants discussed their relationships with other instructors in their departments, colleges, and institutions more broadly, CIS instructors focused much more on their relationships with each other in their interviews. CIS instructors shared process-oriented guided inquiry learning (POGIL) activities and cooperative quizzes within their science departments but needed to discuss interactions with other teachers. This general lack of discussion about other teachers may be related to their relative isolation as A&P instructors or may be due to the nature of the interview questions asked of CIS instructors, as most of these teachers work closely with other teachers in the school, just not around the topic of A&P.

Professional Development from CoPs Revitalizes Teaching for A&P and Other Subjects.

Instructors in both CIS and CAPER described how CoPs revitalize their teaching through professional development and knowledge-sharing among members. While CIS members tended to discuss CIS and POGIL, CAPER instructors are often members of more than one CoP, with all CAPER instructors including HAPS and other pedagogy-focused organizations.

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CIS, Revitalization of Teaching, and Collaboration.

Several instructors in CIS described how professional development opportunities helped them improve their teaching. Jason, for example, explained how CIS offers professional development related to pedagogy and content.

> ***"With CIS… It revitalized my teaching. I've been teaching for almost 20 years. And I needed a challenge. I needed something new, and CIS did exactly that. Also, with the CIS program, with staff development, the professional development is some of the best we've had - everything from when we had the people from POGIL come in and we met…to having speakers like we had today. It's like, "Wow, this is so cool. How can I bring this information back to my students?" Because as teachers, oftentimes we don't get the science PD portion of it. We get methods, we get the assessment, and we get technology when we don't necessarily get the content PD. So getting that content PD plus still getting the methods of using inquiry, again, has really revitalized my teaching. I think it's made me a better teacher. I think my students have benefited from it. I think I challenge my students a lot more than I probably did in the early years of my career."***

We questioned all CIS instructors during the interviews, and just like Jason, we recorded and analyzed their responses. We discussed the impacts of learning POGIL and developing POGIL materials within the CIS program to varying extents. This development of prepared and shared materials ties directly in with the processes necessary to create long-term communities of practice (Bernstein-Sierra & Kezar, 2017).

Most CIS interviewees described collegiality and knowledge-sharing among members of the CoP and Lowery discussed how the leader of the CIS A&P program (co-author MJ) encourages CIS members to discuss everything from the highs and lows of teaching to specific methods.

> ***"But it's truly… it's kind of like a family, you know, you have a bad day, you know, you had a bad school year. And everyone's like, 'It's okay, we did too', or you know, these are highs, these are lows, and you can feel like you can tell them everything. Like, 'I do not know how to do this.' And everyone's like, 'Here, I've got this lab, I've got this activity.' And it's so cool. I love that. And Murray encourages us to do that. He encourages us to share things with people and get together and do things. You know what I mean? Today, we just shared a folder, because I had a really cool lab that someone wanted and she had an idea for something for me. And so we just shared it. And I love that opportunity that we can do that."***

CIS participants have developed spaces for sharing and collaborating during professional development days and through the networks that instructors have created amongst themselves, yet another indicator of a sustainable community of practice (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

CAPER, CoPs, and Knowledge Sharing.

Eight out of twelve (which we define as most) participants in CAPER are members of more than one organization focused on STEM education or pedagogy more generally, with all of them being members of HAPS. DJ Nemzer, an active member of several CoPs, described how these organizations have led her to a network of colleagues across the US.

> ***"I have colleagues all over the United States that I feel like, give me more inspiration and give me more ideas and more opportunities than you're going to get from just directly in your own department or your own surroundings."***

Cross-pollinating with instructors around the US opened DJ Nemzer's eyes to more possibilities than what she can find in her institution alone. Esry described her experiences as a peer reviewer for Quality Matters, where she contributes to and learns from other instructors' online course designs.

> ***"Especially in an online setting, one of the big influences, I think is Quality Matters. And I've had one of my courses actually go through that process, and to kind of look at the different standards. And plus, I've been a peer reviewer, and I still am the peer reviewer, for Quality Matters. So I've actually gotten a chance to look at other people's courses. And so because of that, I could see ideas that other online instructors have used. And sometimes I've stolen a few of those ideas and adapted them."***

While Esry focused on online learning and pedagogy, Kim interacted with a STEM education professional development community similar to CAPER.

> ***"I have been interacting with EDU-STEM. It's a science education collaborative network with the University of Minnesota. So for the last couple of years, [I've] kind of been interacting with them. We've been working on a couple of papers, and just kind of intermingling and discussing amongst science faculty ways in which we can improve student learning, diversify our teaching styles, and then also be able to deal with students, or I guess, assist student grit, or their ability to persist through these science courses."***

Kim has found a CoP of science faculty who are sharing ideas for how to support students as they take challenging science courses such as A&P. While some participants are involved

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with several organizations or find support and development opportunities within their institutions, several participants are deeply involved with HAPS as both a source of professional development and knowledge-sharing. Heather, for instance, described HAPS as a safe space to continue learning and asking questions, no matter how long a person has been teaching A&P.

> ***"I think HAPS is the main one. I see in that community a bunch of people who are lifelong learners and educators who continue to want to learn, and I think that's really encouraging. They're always asking each other questions. I love that on the message boards… there's a range of questions that I'm like, 'Whoa, I hadn't even thought of that.' And 'Oh my gosh, I knew that 10 years ago.' And so it just feels like a really comfortable place to sort of open yourself up and not be afraid to ask us questions. And then, even textbook authors are on there asking questions. That's super encouraging to feel like it's okay to be like, "Hey, I don't understand this thing." I think that has been really beneficial."***

Tom Smith has been deeply involved with HAPS, serving on multiple committees. He also indicated that he finds the online networking aspect of HAPS informs his teaching practice.

> ***"I spend a lot of time on social media with them. And so… we get to know each other and our different teaching strategies. And so that's been really helpful in terms of perspective on inclusion in the classroom, as well as just overall teaching strategy."***

As discussed throughout this paper, CAPER participants have found supportive CoPs in several spaces that allow them to focus on specific teaching and professional development aspects. These CoPs often provide professional development opportunities and spaces for sharing and collaboration among members (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

CIS and CAPER on Professional Development and Knowledge Sharing.

While CIS members rely predominantly on CIS as their CoP, most CAPER participants are often active in two or more CoPs, focusing on different types of STEM education, online education, or pedagogy. These educators find professional development opportunities and networks of like-minded educators who share tips and discuss ideas outside the formal CoP spaces.

Leadership in CoPs

Focusing on CIS as a CoP allows us to look more closely at the nature of leadership in STEM education CoPs. As with many CoPs in the STEM education space, the CIS A&P program benefits from a strong and charismatic leader, Murray Jensen, who has been a part of the CIS A&P program since the beginning. Several participants highlighted the freedom that Murray allows them in their classes, emphasizing that they can teach any A&P content as long as they integrate cooperative quizzing and inquiry into their courses. Sandy explained several aspects of how Murray leads CIS A&P.

> ***"Well, I like I mean, Murray's amazing since day one, once you're in the program. He makes you work to get into the program, or at least he made me work to get into it. I feel like he loves being a teacher and teaching high school. You can tell he values high schoolers, which is kind of cool. So he values education and has your back and he gives you all the support you need. And I love that he gives you the freedom to go deep on certain subjects if you're really into something, and as long as you're doing the few things that he wants to make sure you have done, which I think align with what I talked about at the beginning with critical thinking study skills, Co-Ops, working in teams, as long as you're hitting that stuff, preparing kids for the world, the actual content that you teach isn't as huge, which I think is really refreshing. So I really like that aspect."***

CIS instructors like Sandy appreciated Murray's structured pedagogical requirements and the freedom in terms of content. They also recognized Murray's love of teaching and respect for high school students as essential to his leadership.

However, some CIS instructors also found him "a bit random" as they switched between projects without necessarily completing them. For instructors, this occasionally made them feel that the professional development could be more cohesive when they wished to continue with projects they liked for a longer time.

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As the CIS A&P CoP develops, some instructors felt they could organize and share more. Nina explained that community members can step up at this point and take more leadership roles within the CoP.

> ***"I realize we've had COVID and but even before that, I feel like our time could be better utilized with the people in this group. There are 30 people, there's one Murray. I don't think Murray has to do everything. But that maybe with the 30 of us, we can bring things now to the party and share. This is something that I have done, and it's worked really well. It's worked really well and just a lot more sharing of ideas from the 30 of us who work together... We should probably revisit all the good things that we have and that many of us use and kind of bring that to the forefront. Because even Murray told us yesterday, 'Hey, you're my kids, but you're kind of grown-up now. And I got some other things going on. So you know, take it away.'…There are so many people here who are great teachers and just to have a forum where we could share some of the time-tested and high-quality educational materials, labs, models, and investigations that we've really polished in our teaching…with our colleagues so that everybody can gain from that. That'd be my one thing. Let's take a look at our format for professional development and revisit that."***

Nina clearly stated that it is time for CIS A&P to look at the current leadership structure and format of professional development and knowledge sharing and adjust it to fit members' needs. Taking on leadership positions and adjusting professional development days can increase the longevity of CIS A&P (Bernstein-Sierra & Kezar, 2017; Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

Discussion

While most CAPER participants are members of more than one CoP, none of these groups focus on A&P educational research, and CIS participants did not indicate involvement with other CoPs. The theoretical framework supports this as the CIS teachers are K-12 educators engaged in an apprenticeship/mentor CoP throughout their professional training (Lave & Wenger, 1991; Wenger, 1998). In contrast, the CAPER participants, as higher educators, typically receive little pedagogical training and, therefore, need to seek those CoPs in other areas (Edwards et al., 2015; Flynn et al., 2017; Parker et al., 2016). Recognizing existing long-term CoPs, such as CIS and HAPS, and their impact on educators, can inform how short-term BER projects, such as CAPER, can become long-term communities of practice. CIS and CAPER participants emphasized the importance of physical or online conferences and continued engagement through listservs within their CoPs (Kezar et al., 2017). Therefore, the CAPER research team should consider creating and maintaining a listserv and, potentially, a blog-style website and webinar space to support the continued sharing of information about A&P educational research. A vibrant listserv already exists for the CIS community, although a blog-style website and webinar space could be practical additions to continue the CoP for CIS.

Reflecting on the current shifts in CIS instructors' perspectives toward the balance of power within the CoP as it matures, both CIS and the CAPER research team should think carefully about how to structure leadership within the long-term CoP. Assuming that the CAPER CoP will not find a consistent funding source, the CAPER research team and CC instructors may want to select volunteers to maintain the listserv and website, organize occasional webinars, and make blog posts (Kezar et al., 2017). Within CIS, those conversations have begun to examine the current leadership structure to make improvements. Given that the CAPER research team has provided the initial digital infrastructure for educational anatomy and physiology (A&P) research to begin, it will likely naturally form a community of practice (CoP) similar to the structure for CIS.

Seeing as CAPER recruited most participating instructors through HAPS, it is likely that creating an education research branch and listserv within HAPS would overcome funding and infrastructural barriers to the development of a long-term CoP. By integrating with HAPS, A&P educators interested in educational research could join HAPS conferences to reinforce their community and reinvigorate online engagement throughout the year.

In terms of faculty mentoring, both CIS and CAPER could potentially benefit from the faculty mentoring described to be used by Project Kaleidoscope (a STEM CoP centered on educational reform), which provides a framework for mentoring, including building relationships and establishing formal mentor relationships (Kezar et al., 2017; American Association of Colleges and Universities, 2023). There is a layer of this within the current CAPER project, with each participant having a formal mentor during the project time that could become a longer-term mentor relationship. The CAPER program also utilizes former participants as mentors, providing more opportunities for building relationships as mentors. Within CIS, as the discussions regarding leadership structure continue, formal mentoring should be considered a leadership opportunity for some longer-standing members.

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Conclusion

This study of two unique STEM education spaces - one for high school A&P instructors teaching a college-level course and one for CC A&P instructors engaging in educational research - reveals that long-term CoPs like CIS and HAPS share many of the characteristics described by Gehrke, Kezar, and Bernstein-Sierra in their studies from 2017 through 2018. While their isolation forms differ, members of CIS and CAPER find CoPs outside of their institutions to get the support they need to continue growing as educators (Kezar et al., 2017). CIS and the CoPs that CAPER participants are involved with provide them with professional development opportunities and informal networks of peer teaching and mentorship (Kezar et al., 2017). Several CAPER participants described their progression through different committees in HAPS and other leadership roles in pedagogy-focused CoPs (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017). CIS has thrived under a strong leader and is on the brink of evolving, with some participants hoping for leadership opportunities and shifts in the organization of professional development programming (Gehrke & Kezar, 2018; Kezar et al., 2017; Kezar & Gehrke, 2017).

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Appendix 1: CIS Interview Questions

1. What degree and licensure do you hold?
2. How long have you been teaching?
3. How long have you been teaching in CIS?
4. How do you describe your role as a teacher?
5. How do your students learn science best?
6. How do you know when learning is occurring in your classroom?
7. What does a typical day in your classroom look like?
8. What do you feel is the most effective way to teach students a new concept?
9. Please describe your experience in CIS - what are some things you like and what could be improved?
10. What is the most valuable concept/idea that you've learned in CIS?
11. What is something you learned in CIS that didn't work for you?

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Appendix 2: CAPER Interview Questions

Hello, thank you for taking the time to talk with me today. I'm going to ask you a few questions about your teaching practices, experiences, and beliefs. This interview should take no more than an hour of your time. We will be using a pseudonym when we write about you in articles. What would you like your pseudonym to be? You can always change it later.

Great! Do you have any questions before we begin?

1. How long have you been teaching?
2. In what teaching context have you been most satisfied?
3. Can you talk about some of your past A&P experiences?
4. What have been some of the most important influences to your teaching up to this point?
5. How do you describe your role as a teacher?
6. How do you maximize student learning in your classroom?
7. How do you recognize when something is effective in your classroom? What do you look for?
   a. What about when something is ineffective?
   b. How do you react to signals of effectiveness or ineffectiveness?
8. How do your students learn A&P topics best?
9. How do you decide what to teach and what not to teach in your A&P classes?
10. When do you decide to move on to a new topic in your A&P classes?
11. What are some of your personal goals for your teaching?
12. In what ways are your teaching goals beneficial to your current students?
13. Please describe any gaps between your teaching goals and what you are currently able to achieve in your classroom?
14. Describe any internal and external constraints that are preventing you from achieving your teaching goals.
15. Where do you turn to for new information or solutions to teaching situations that come up?
16. Are there any aspects of your teaching that you are not satisfied with at this time?
17. What professional communities do you most closely belong to? In what ways do they affect your teaching and/or research practice?

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Appendix 3: Codebook

Theme	Explanation	Example
Isolation leading to the necessity of communities of practice	Participants discuss how they find support in communities of practice as a response to isolation in their own institutions.	"There are four people in my science department…but only one other person teaches life science. So I just don't have a lot of other people as resources. College in the schools has given me a huge pool of like-minded educators in that way." - Nina
Collegiality within institutions as counter example	CAPER participants highlight how they approach their colleagues for support. Some of these participants also mention that they are not active members of any CoPs outside of their institutions.	"My colleagues. We do have amazing people in our department, and within our college and school, and I've been so lucky from day one that they just kind of took me under their wing. As an adjunct, it was very isolating. It was extremely isolating. I had no idea what I was doing…But my colleagues here have been beyond supportive… Just this stuff that takes so much time that you don't even have time to prepare your course or think about pedagogy. These people have supported, allowed me to grow so much as an instructor. So that's a huge resource. "Hey, I have this student that behaved this way." Snap a picture of an email from a student, "Hey, what do I do here?" We have a group text message just for biology. We have a group text message with faculty from different departments. So much support from colleagues is a huge one." - Yara
Professional development within communities of practice revitalizing teaching	Both CIS and CAPER instructors discussed the professional learning opportunities and knowledge sharing within their CoPs as giving them more ideas and revitalizing their teaching.	"With CIS... It revitalized my teaching. I've been teaching almost 20 years. And I needed a challenge. I needed something new and CIS did exactly that." - Jason
Leadership in communities of practice	Participants in CIS often mentioned Murray Jensen, their leader, and the positive and negative aspects of his leadership.	"Well, I like I mean, Murray's amazing since day one, once you're in the program. He makes you work to get into the program, or at least he made me work to get into it. I feel like he loves being a teacher and teaching high school. You can tell he values high schoolers, which is kind of cool. So he values the education and has your back and he gives you all the support you need. And I love that he gives you the freedom to you go deep on certain subjects if you're really into something, and as long as you're doing the few things that he wants to make sure you have done, which I think align with what I talked about at the beginning with critical thinking study skills, Co-Ops, working in teams, as long as you're hitting that stuff, preparing kids for the world, the actual content that you teach isn't as huge, which I think is really refreshing. So I really like that aspect." - Sandy

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