

Understanding the Practices and Challenges of Networked Orchestration in Research Communities of Practice

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Work and learning communities have become increasingly networked to support their members in developing the skills to solve complex, real-world problems. Though disciplinary knowledge remains important to tackle these problems, working effectively in these modern-day communities of practice demands the ability for one to learn how to access networked support (e.g., venues, tools, resource guides, or peers) throughout the community for one's needs. Against this backdrop, we study *networked orchestration*—how community members access and learn to access networked supports—in a community of practice for undergraduate research training. Through field observations and in-depth interviews, we find that students in the networked research community dynamically engage with their mentors and peers across multiple venues throughout the week in order to identify, clarify, and resolve their needs. Mentors in the community monitor how students are engaging with the supports available in the network, and provide coaching on effective strategies when students are ineffective on their own. Finally, we surface the challenges involved in each of these processes and offer practical insights for future ecosystem-level *networked orchestration technologies* that have an understanding of the interactions occurring across the venues and tools in a community, and can support the learning and practice of effective access strategies. Our paper presents important insights for supporting people's work and learning needs in networked future workplaces and learning communities, and provides guidance on designing new technologies for supporting networked ways of working and learning.

CCS Concepts: • **Human-centered computing** → **Empirical studies in HCI**; **Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: networked orchestration; research communities; communities of practice

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1 INTRODUCTION

There is a critical need for workplaces and learning communities to support their members in developing the skills to solve complex, real-world problems [35]. Fulfilling this need involves supporting community members in recognizing when work and learning needs occur, and coordinating resources from across an entire organization to resolve those needs. Doing so has led to significant changes in how work and learning are conducted in organizations. For instance,

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engineering organizations have adopted agile working practices [56], project tracking and collaboration tools that enable them to track, prioritize, and resolve work obstacles [1, 3, 7], and flexible organization structures [51] that allow for dynamic teaming from across the organization [19]. Learning communities have developed methods of teaching undergraduate research training [62] and design inquiry [39, 47] by supporting members in learning key skills involved in these tasks, such as planning work and collaborating with peers for feedback.

As work and learning communities become increasingly networked and organized to support a myriad of technology-mediated collaborative interactions, we can begin to view them as *communities of practice* that provide access to a wide range of supports (e.g., venues, tools, resource guides, and peers) for working and collaborating. Though disciplinary knowledge remains important, the most critical skill for working effectively in these communities is the ability for one to navigate the venues and tools available across the community to support their work and learning [34, 37]. Doing this well involves recognizing when one's own resources are insufficient for reaching their goals (i.e., the "needs" one has [25, 45]), knowing how different supports in the community can resolve each need, and planning to address needs over multiple interactions with different parts of the network. Alongside this process, coaching is provided to help people learn how to effectively access support opportunities in the network. We refer to this process of accessing and learning to access community support in networked communities of practice as *networked orchestration*.

Despite the prevalence of these networked communities, our current understanding of how community members actually *access and learn to access the networked supports they are provided* and the associated challenges are limited. Within CSCW, this has been an overlooked area of focus relative to *providing access* to a network of support through the development of social structures and tools within the network. For instance, significant prior work in CSCW has studied the benefits of providing access to resources [21, 22, 47, 62] and advanced tools for supporting specific aspects of collaborating and help-seeking (e.g., finding or connecting to a resource [10, 11, 31, 41]), but less has focused on understanding the practices and skills involved in accessing the provided structures and tools, and how such practices and skills can be facilitated and learned (e.g., through coaching). This understanding is critically important for advancing the future of work because the effectiveness of a community of practice for supporting complex work is ultimately determined by how people access the networked opportunities that are available, and not only by making opportunities available in the first place [34]. In other words, the wide array of venues and tools embedded within networked communities enables more opportunities for community support to be accessed when required, but also increases the complexity of navigating and making effective use of those opportunities. It is against this backdrop that our understanding of the ways of accessing and learning to access support opportunities in highly networked communities, and the associated challenges, has not kept up with their provision.

To address this gap, our paper examines networked orchestration and the process of accessing a network of support in the context of undergraduate research training. We study one mature deployment of Agile Research Studios (ARS), a research community of practice that provides various socio-technical supports for learning how to lead independent research projects [62]. These supports include *venues* where students can access peers and mentors from across the community who provide support and coaching for their work and learning needs, and *work and collaboration tools* to facilitate the interactions in those venues. In these ways, ARS resembles the kind of networked communities that are becoming increasingly prevalent in workplaces and learning communities.

We conducted field observations and in-depth interviews with members of the ARS community over a 20-week period. Our analysis reveals that students in the networked research community developed several network access strategies to dynamically engage with their peers and mentors across multiple venues throughout the week in order to identify, clarify, and resolve their needs;

however, students also struggled with using community supports when they could not identify their own needs, track expertise across the community, and reach out to peers who they were unfamiliar with. Mentors in the community monitored how students were using their access strategies to engage with the community's network, and provided coaching for more effective strategies when students were ineffective on their own. However, mentors struggled with maintaining awareness of students' networked access patterns (i.e., they were not visible to mentors), and with tracking students' progress on how well they were developing access strategies over time. Given these challenges, we close with design implications for future *networked orchestration technologies* that can aid networked communities in the process of learning and coaching network access strategies.

Our paper makes three contributions to CSCW. First, our analysis uncovers the complexity in navigating a support network to address one's work and learning needs, namely the work involved in monitoring needs, identifying appropriate venues or peers, and using multiple interactions across the network to address these needs. These findings provide insight into the previously hidden work that goes into effectively accessing support for one's needs in networked workplaces and learning communities. Second, our analysis uncovers the difficult process by which mentors coach their students in learning effective network access strategies that requires them to monitor how students are engaging with support opportunities across the community and help students practice effective strategies when they are ineffective on their own. This builds on existing work in the learning sciences on how students are coached to approach complex work [14, 39] by adding insight into the additional work involved in coaching for learning network access skills. Third, we argue that future technologies that support the learning and coaching of network access strategies require an ecosystem-level approach where they can monitor for and facilitate effective ways of working across a community's venues and tools. This approach deviates from prior work in CSCW that has primarily focused on the provision of access or the support of an individual in a single venue, not the process of learning to access a network of venues, tools, resources, and peers for one's needs.

2 BACKGROUND

We are interested in understanding how people access and learn to access networked supports (e.g., venues, tools, resources, and peers) in work and learning communities. In this section, we review the development of these networked communities, and then discuss prior research that has focused on understanding how people learn to access support in these kinds of communities.

2.1 Development of Networked Work and Learning Communities

Work and learning communities have become increasingly *networked* in order to provide their members with access to many forms of support and collaboration for their work and learning process. An early example of such networked workplaces were collaboratories: organization structures that facilitated collaboration between researchers from around the world by providing shared access to scarce or expensive instruments, computational resources, data, and more over the internet [21, 22]. More recently, workplaces have been adopting less hierarchical organization structures [46, 51] and agile work processes [56] that promote collaboration from different parts of the organization (e.g., research; development; testing; manufacturing) to address emergent needs, as well as collaboration tools that support these ways of working (e.g., Asana [1]; Jira [3]; Trello [7]).

As these communities become increasingly networked by providing a myriad of technology-mediated collaborative interactions, we can begin to view them as *communities of practice* where people with similar domain interests use shared practices, venues, and tools to support their work and learning process [60]. What makes these communities effective is the ability of its members to *access* the venues and tools available in the community since these are the situations in which work and learning actually happens in communities of practice [37]. To that end, significant work

in CSCW has focused on ways of *providing access* to support opportunities through better socio-technical frameworks and tools. These include frameworks that suggest effective social structures for different learning needs in design and research work [47, 62], and tools that assist people in connecting to expert helpers in the community [10, 11, 40, 41, 43] and accessing external help [31]. The inclusion of these frameworks and tools enables communities to more readily coordinate support for the needs that arise when working on complex or ill-structured problems [50].

2.2 Learning How to Access Support in a Network

While these venues and tools are necessary to facilitate the complex work of modern workplaces, their inclusion increases the complexity of working and learning in a community. Accessing support in a network is challenging because it requires people to navigate a large number of potential strategies (i.e., ways of using support in the network) that one can attempt to address their needs, and to manage one's working and learning process with networked support in mind. Further challenges can also arise when people do not know which support opportunities are available or how to use each opportunity well for their work or learning needs [25]. Given the complexity of navigating modern communities of practice, **the actual use and effectiveness of the community to support its members hinges on how well people are able to integrate these supports into their work or learning process** [34]. In other words, we must look beyond the provision of access (a common focus of CSCW research) to instead study *how people actually access and learn to access* the provided support opportunities, and the associated challenges within that process.

One lens through which the process of accessing support has been studied is expertise sharing, the collaborative and social process by which people learn about the skillsets of their peers and seek out support for their needs [8, 9]. Prior literature has examined the importance of developing social capital in organizations [32, 44] and having people in close proximity to one another [27] for the expertise sharing process to occur, and how communities of practice are effective in supporting expertise sharing [38]. While this remains important in our study, people in networked communities also rely on the many venues and tools available in their networks for support. This requires them to engage with the expertise sharing process to connect with peers, and also learn how to plan their work or learning process around the availability of support opportunities in their network.

To that end, recent studies have examined how members of a community may access and use resources available to them to advance their work and learning in response to their changing needs [29, 30, 48]. However, these studies have primarily focused on understanding the emergent uses of support in less structured communities. In contrast, our work focuses on understanding how people learn to navigate the variety of venues and tools found in established communities, and highlight the challenges that arise in accessing support across a complex network of support. Our analysis reveals the dynamic processes involved in accessing and learning to access a myriad of structured venues, collaboration tools, and peers made available in a learning community, along with the challenges that hinder effective access strategies from being used.

In addition, we are also interested in understanding how mentors help their students learn to access venues, tools, resources, and peers in a community. While there is an existing body of work on coaching people to more effectively approach complex work, this literature tends to focus on supporting individual ways of working (e.g., by developing strategies for assessing project risks [14] and planning work around those risks [39]) and not on developing effective strategies for accessing support across a network. Providing coaching on how to assess ones' needs, plan, and replan interactions in a network is crucial for working in networked communities, especially when a person's needs are constantly changing as they progress their understanding of their work [50]. To that end, our analysis contributes to this literature an understanding of how mentors can help learners develop network access skills. In particular, we highlight the ways that mentors

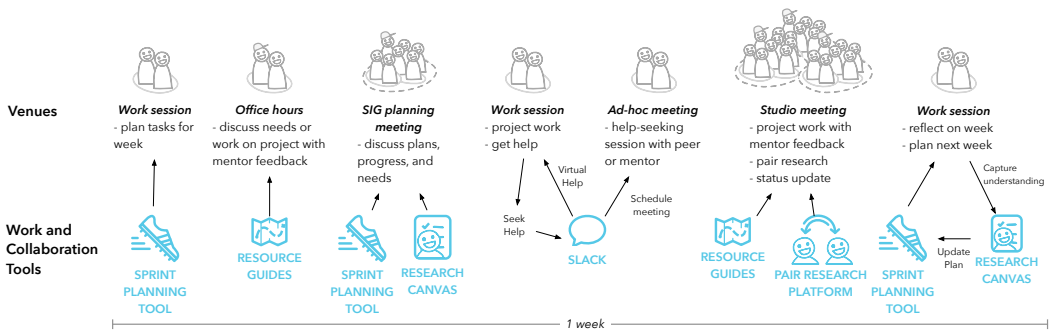


Fig. 1. ARS provides venues throughout the week for accessing peers and mentors, and work and collaboration tools that support the activities in those venues. Working well in an ARS involves integrating networked support opportunities found in the ecosystem throughout the week as part of one’s work and learning process.

maintain awareness of learners’ ineffective network access strategies and scaffold the practice of more effective strategies, and the associated challenges. Based on this analysis, we contribute design implications that argue for the need for ecosystem-level technologies for helping students and mentors in the process of learning to access network support and coaching for access.

3 RESEARCH SETTING

We conduct our study of networked orchestration in the context of undergraduate research training situated within a community of practice using the Agile Research Studio (ARS) model [62]. ARS provides research experiences to undergraduates in which they practice core activities in conducting research, such as designing a research plan, collecting and analyzing data, and preparing manuscripts. It does this by providing students with several *venues* for accessing peers and mentors from across the community who provide support and coaching for their work and learning needs. ARS also adopts *work and collaboration tools* that facilitate support interactions throughout the community. Working effectively in this community involves directing one’s work and learning process while integrating support opportunities found in the network throughout the week.

Our research takes place within the Design, Technology, and Research (DTR)¹ community at Northwestern University during the Winter 2019 (January 2019 - March 2019) and Fall 2019 (September 2019 - December 2019) academic terms (10 weeks each; total of 20 weeks). DTR is a long-standing ARS that started in the Spring of 2014 with 7 undergraduate students and 1 faculty mentor. During our study, DTR as a whole had 18 members (11 undergraduate students; 5 Ph.D. students; 2 faculty mentors) in Winter 2019, and 17 members (9 undergraduate students; 6 Ph.D. students; 2 faculty mentors) in Fall 2019; in prior terms, DTR has been as large as 25 members. Alongside this growth, new venues and tools were created as the community’s needs shifted. For example, Special Interest Groups (SIGs) composed of multiple students working on related projects were created early on so that it was tractable to mentor more students at once and to promote collaboration between the students. As another example, research canvases were created in Fall 2016 to help students capture their research understanding, assess potential gaps, and plan future research tasks to address them [39].

Students enter and exit DTR during every 10-week academic term, with most students participating over a prolonged period of time (normally over a year). To support new students, former DTR students developed an onboarding program in which incoming students were paired with an

¹<https://dtr.northwestern.edu/>

onboarding mentor—a more senior student in the community. The onboarding mentor and student would meet in the first week to help the student learn about the community’s working processes, venues, and tools during their first week. They would continue meeting weekly throughout the term to discuss how the student’s research was going, how working in DTR was, and if they had any questions or concerns. This allows for new students to quickly integrate into the community, and begin to learn how to work in a networked community.

In the rest of this section, we provide more details about the venues and work and collaboration tools present in the instantiation of ARS used by the DTR community; see Figure 1.

3.1 Venues

DTR implements the ARS model, which provides several venues throughout the week where students can access peers and mentors for support on their needs and for coaching. These include:

- **Work sessions** where students work on their own or with their teammates throughout the week as needed to meet their planned deliverables. Sessions early in the week often have a greater emphasis on planning for the rest of the week, and sessions later in the week involve more reflection and updating of plans based on the current week’s progress.
- **Office hours** held by mentors allow students to discuss specific project needs, or work on parts of their project while the mentor provides feedback on it and their working process.
- **Special Interest Group (SIG) planning meetings** where students primarily discuss their research plans for the week, but can also use the meeting to solicit feedback on any other needs they may have. SIGs consist of up to 2 project teams working on related research topics, a SIG head mentor who is a Ph.D. student working in the same research area, and the faculty mentor. SIG meetings typically occur at the beginning or middle of the week, and are attended by all the students in the SIG and their mentors.
- **Ad-hoc meetings** that occur whenever students need help from their peers or a mentor outside of scheduled venues (i.e., office hours; SIG meetings; Studio meetings).
- **Studio meetings** which are community-wide meetings that occur every Friday afternoon consisting of (1) a structured learning and practice time where students work on part of their project (e.g. writing and critiquing design arguments; writing a study design) while the faculty mentor provides feedback; (2) a Pair Research session [43] where students pair to provide each other with help on their projects; and (3) a Status Update presentation from a project team on a portion of their work to the entire community for feedback.

The above venues occur in various physical spaces (e.g., classrooms; faculty offices; shared collaboration spaces), with two of note. The first is a small room specifically for use by DTR members that is fitted with whiteboards and computer monitors in which students work individually or with their teammate, hold meetings or conduct user tests, and have ad-hoc discussions with other students. The second is a much larger space outfitted with whiteboard walls on three sides of the room that is used to hold weekly Studio meetings.

3.2 Work and Collaboration Tools

The ARS model also provides DTR with a set of work and collaboration tools that facilitate the interactions within the venues described above. These include:

- The **Sprint Planning Tool** which helps students plan out their research tasks for the week, track progress towards their deliverables, and note potential obstacles in accomplishing their tasks (e.g., not knowing how to implement a feature for a prototype). Students update the tool throughout the week. They are also discussed in detail during weekly SIG meetings.

- **Resource guides** which are digital documents developed by the students and mentors for many of the research tasks conducted in the community. For example, these include guides for: conducting needfinding with users; writing a study design; preparing a manuscript; and many more. These resource guides are used throughout the week, with students being pointed to them by mentors and peers if a guide is appropriate for their needs.
- **Research canvases** which are structured representations of the research work that help students track their current knowledge about their research project and plan for next steps based on gaps in their knowledge [39]. Research canvases are routinely updated as progress is made, and are frequently referred to during SIG meetings and office hours by mentors.
- A **Slack** team [5] for online announcements and conversations. Slack is used by students to communicate with their mentors and with peers outside of venues. In addition to direct messaging, the team includes dedicated channels for each SIG, project team, and themed help channels (e.g., #help-javascript; #help-ios) where relevant discussions can occur.
- The **Pair Research Platform** to facilitate Pair Research sessions at each Studio meeting [4]. During a session, each student reports something that they need help with and their ability to help others with their help-requests. The platform then matches students based on their ability to help each other.

4 METHOD

We seek to understand the process of accessing and learning to access supports in a networked community. Our study is guided by the following research questions:

RQ1: How do members of a networked community access support opportunities for their work and learning needs?

RQ2: How do mentors of a networked community coach effective network access strategies?

RQ3: What makes it difficult for a community to do these practices well?

4.1 Participants

We interviewed a total of 13 undergraduate researchers, 4 Ph.D. students who serve as SIG heads, and 2 faculty mentors. The interviewed undergraduates were in the DTR for 1 to 3 academic terms ($M = 2.46$), while the interviewed Ph.D. students were SIG head mentors for 4 to 16 academic terms ($M = 9.25$). Each SIG head mentored 1-2 project teams with up to two undergraduates per project. One faculty mentor was involved with the community since its inception, and the other for a period of two years (6 academic terms) at the time of study. The first faculty mentor was involved in all 5 SIGs, while the second faculty mentor co-advised one of the SIGs. For privacy, all participants were given pseudonyms. Table 1 in Appendix A provides each participant's pseudonym along with details about their role and time in the community, which SIG(s) they are part of, and the SIG's research area. Two of the paper's authors—Henry and Kyle—are both members of the community as a faculty member and Ph.D. student respectively. Kyle was not interviewed during the study, and no observations were conducted during his SIG meetings.

4.2 Procedure

Our analysis is grounded in participant observations and in-depth interviews with members of the DTR community. The goal of the field observations was to understand how SIG meetings helped students think through the planning aspects of their research work, and how they plan to use the different community supports over the week. During the Winter 2019 term (January 2019 - March 2019), we conducted 8 field observations at SIG planning meetings. In these meetings, mentors and their students would discuss the student's research progress, their research plan for the next week,

any current or anticipated needs for the upcoming week, and strategies to access support in the network for them. Each meeting lasted approximately 1 hour, and the observer took detailed field notes on the conversation between the presenting students and others in the room; the observer also noted any gestures, facial, and body expressions that indicated agreement or discomfort. All field observations were conducted by the lead author in-person.

In addition to the field observations, we conducted in-depth interviews with students and mentors of the DTR community. The goal of the interviews was to understand students' and mentors' experiences working and coaching in a networked community, respectively, and the associated challenges. During the Winter 2019 term (January 2019 - March 2019), we conducted our first round of interviews alongside the field observations with 5 undergraduate students, the 4 SIG head mentors, and the 2 faculty mentors. For students, we focused on understanding how students determined their work or learning needs, and planned their week around those needs. For mentors, we focused on understanding how mentors help students identify the needs for their research project and the potential support opportunities they could use across the network to resolve them.

We also conducted a second round of interviews that was informed by the initial themes generated from the Winter 2019 term of data collection (more details are provided in the following section). During the Fall 2019 term (September 2019 - December 2019), we interviewed 8 additional undergraduate students who had not been interviewed in the previous term, and re-interviewed the 4 SIG head mentors. For students, we probed for the considerations they made when selecting venues (e.g., why go to a mentor versus a peer for a need?), how that would influence their work or learning process, and any challenges they faced. For mentors, we probed for how they helped their students learn to use networked supports, what information they needed to be able to coach this process, and any challenges they faced.

Before each interview, participants were given informed consent and asked permission to take audio recordings that were later transcribed for analysis. All interviews were conducted by the lead author either in-person or over Slack video calls if the participant was not available in-person, and were approximately 1 hour long. In summary, our analysis is grounded in approximately 8 hours of field observations at SIG planning meetings and 25 hours of interviews ($M \approx 1.09$ hours long).

4.3 Data Analysis

We analyzed our data using a thematic analysis approach [12]. During the coding of our data, our goal was to identify the processes and challenges that arise for students when navigating community's venues, tools, and resources and for mentors when providing coaching support. Our analysis of the Winter 2019 data began to uncover a high-level working process that occurred in the networked research community, but lacked details about how students and mentors enacted each stage of the process effectively. This led to us revising our interview protocol so that we could further understand the skills and knowledge students and mentors needed at each stage of the accessing or coaching process, and any challenges with practicing those skills or maintaining that knowledge. Our coding of the Fall 2019 data began to uncover the multiple activities that occurred at each stage, along with several challenges that hindered their practice. Once all data was coded, we reviewed the themes generated from both rounds of analysis by going through our data to look for instances that supported or contradicted them. These themes were then iteratively refined by splitting or combining them until they were distinct. We then reviewed all the themes, and finalized the set that we present below. The coding of the field notes and interview transcripts, and the generation and review of the initial themes was conducted by the lead author; all authors collectively refined and finalized the themes.

5 FINDINGS: HOW STUDENTS ACCESS SUPPORTS IN A NETWORK

Our analysis reveals that successfully working and learning in a networked community like DTR is a complex process that requires a single person to engage an entire community of mentors and peers across multiple venues each week in order to identify, clarify, and resolve their needs. As an illustrative example, we walk through Charlie's 3-day process for preparing a Status Update—a presentation or activity from a project team on their current research work that the entire community provides feedback on. Charlie's research project focused on developing applications that enable physical crowds to help each other accomplish tasks around their physical routines, such as picking up coffee for themselves and for someone else on the way to work. At the time of his Status update, Charlie had just started to think about the research contributions his work would be making around the "last mile" problem for package or item delivery, but was still unsure what feedback he was looking for since it was so early on. He also had to prepare the actual Status Update activity or presentation that he would present during the studio-wide meeting on Friday.

With these two high-level needs in hand, Charlie broke down his first need further into brainstorming ideas on his own, and then discussing the ideas with his mentor. After brainstorming, Charlie messaged his mentor, Yousef, over Slack to schedule an ad-hoc meeting to discuss his Status Update plans. However, that meeting, *"ended up not being a lot about the Status Update,"* and instead, they talked about the gaps in Charlie's research project. This enabled Charlie to clarify that his actual need for preparing the Status Update was to understand what gaps were in his project, and to plan the update around those gaps (in Charlie's case, trying to connect findings from a prior study to the "last mile" problem he was studying). With this understanding, Charlie continued his preparations, seeking help from Yousef again over Slack on Thursday, *"to make sure that I correctly internalized what we had discussed, and I didn't misunderstand anything that we were talking about."* For his second need, Charlie had planned to get feedback on the presentation he had prepared during Pair Research at the Studio meeting. Charlie's Pair Research partner helped him realize a better way to structure his feedback request to the community at the start of his presentation by asking for, *"feedback on how well I described these existing approaches and why they don't work, and give me feedback on these specific outcomes"*.

Charlie's journey captures a common process of how students in our study navigated the support opportunities available in the community to address their work and learning needs. In particular, this process is underpinned by three key practices that we identified through our analysis:

- (1) **Monitoring for and assessing needs that the network can support:** students monitor for the needs they have, break them down so that they can be addressed with the support of the network, and clarify them as they interact with venues or peers in the community.
- (2) **Identifying support for needs:** to resolve identified needs, students try to understand what kinds of support different people and venues across the network can provide.
- (3) **Planning and sequencing the completion of needs across multiple supports:** students plan how they will access multiple venues throughout the week for their needs, with each venue offering different kinds of support.

In what follows, we detail how students in DTR carry out each of these practices, and discuss the challenges that can hinder students in accessing networked support for their needs.

5.1 Monitoring For and Assessing Needs That the Network Can Support

Using a network to support one's needs first requires monitoring for the *needs* themselves. Needs arise when a person realizes that their own resources are insufficient for reaching their goals, and that they require external support [25, 45]. In our domain for research work, examples of

needs include getting feedback on research arguments, debugging code for a software prototype, recruiting users for testing, analyzing and writing up testing results, and so on.

As students in DTR would realize their needs while planning their research work, they would often find that their needs were too broad to seek support for, requiring them to break the need into smaller components that different interactions in the network could address. This is necessary because one of the main benefits of having access to a diverse support network is the ability to use the different venues available throughout the week to get multiple rounds of support from mentors and peers. Charlie's earlier story is one example of the process of breaking down needs, where to prepare a Status Update, he plans work across multiple venues where he can get support for different needs (e.g., from his mentor at an ad-hoc meeting; from his peers during Pair Research).

Student's interactions with venues or peers in the community when attempting to resolve a need would also help clarify existing needs and surface new ones. As we saw earlier with Charlie's example, this often happened when students were seeking feedback from their mentors or collaborating with peers. As another example, George recalled an interaction he had during a Pair Research session with a peer where they were brainstorming use cases for his project. George's project focused on developing an application where users would participate in a narrative experience (e.g., a murder mystery), based on their physical location in the world (e.g., different actions if they were at a coffee shop, versus a park). At the time, George was very focused on supporting the authors in creating the narratives since they decided many of the thematic elements of the story, but at the cost of letting the context of the participants (i.e., their location) play a greater role. By working with his Pair Research partner, he realized that he could, "*let loose and sort of approach the problem from a different angle*," by having the author give up some of their control of the story, and let the context-awareness of the system he was building dictate more of the story progression. This idea had not occurred to him prior to the Pair Research session, and gave him another approach that he could prototype in future weeks. In this way, we see how interactions with networked support play a dual role in addressing existing needs and also surfacing new ones that the student will have to consider for future interactions in the network.

In summary, we see that just the act of monitoring for needs in itself is already a complex activity in a networked community. The process involves not only noticing when a need occurs, but subsequently breaking it down to fit a potential venue and realizing when clarified or new needs arise from interactions with the community (and breaking those down, and so on). Due to the overall difficulty of this process, students can still struggle to realize the needs they may have on their own, and require further help from their mentors or peers to identify them [25]. As we will see later, extensive coaching is provided not only for this, as mentors would even in a non-networked setting, but also for how to use the different venues throughout the week to resolve those needs.

5.2 Identifying Support for Needs

As needs become known, one's ability to use the network for support is dependent on how well they understand what kind of help each venue, tool, or person in the network can provide. For venues and tools, we found that members of DTR were able to understand what activities each venue or tool afforded based on their previous interactions with them. For example, Christina shared how the community Slack team easily allowed her to get, "*quick feedback on something just because you can send documents across it*," and to coordinate with other students for studies or interviews for her project. Determining what their peers could support, however, was more involved than learning about the community's venues and tools since it required students to practice the skill of expertise sharing to learn about and keep track of people's expertise in the community [9]. In what follows, we detail how the interactions with venues and tools in DTR's network helped students in the expertise sharing process, which in turn helped them access support for their needs.

Interactions in the co-located venues present in DTR provided students with passive visibility into the current expertise of their peers [53]. For example, one activity during Studio meetings involved students working on their research on whiteboards while a mentor circled the room to provide feedback. By having students externalize their work on the whiteboards, others in the same physical space were able to see what concepts they are working on (e.g., design arguments for potential prototypes; writing a study design; working on research contributions; etc.) and their current knowledge of the concept. This allowed Scott to, “*get a sense of how comfortable someone might be in some concepts or just finished [a concept]*,” which informed his personal model of the community’s expertise that he could use to seek out support later on if needed [58]. Outside of the Studio meeting, Jason also highlighted how the shared community space where students would frequently work throughout the week enabled him to, “*look over and ask what people are working on*,” informing him about who could help with things that he may need help with.

Collaboration tools used by DTR also facilitated activities that helped students understand their peers’ expertise. One crucial tool for this was Pair Research, which was used to pair students together for working sessions during the weekly Studio meeting where they would help each other with something on their respective research projects. These pairing sessions both helped to resolve existing needs, and also provide insight into what others are working on or what skills they may have that could help with future needs. Melissa recalled one event where she knew to reach out to a peer because she remembered him, “*asking questions about his interface during a Pair Research session in Studio, and what I was working on reminded me of the conversation we had had*.” Over time, this enabled participants, like Alex, to easily seek help from others outside of Pair Research since he had interacted with most of the community and knew their expertise:

“Given that now I have pretty much got help from everyone at least once in DTR even probably some people in [research lab], I now know what kind of conversation I can expect to have with each person and what kind of outcomes I can get, and then using that information just point me in the right direction.” -Alex, Undergraduate

Beyond the direct interactions Pair Research enabled, we found that the design of the tool helped inform the expertise sharing process of students by providing social translucence into the work community members are doing and the expertise they have [20]. For example, Christina also shared that in addition to Pair Research pairings, she also learned about what others were doing by, “*seeing what people’s help requests are at the beginning of Studio before we’re paired up*.”

Despite the existing venues and tools supporting the process of expertise sharing, students reported struggling with maintaining awareness of expertise across the entire community as their peers’ work progressed and knowledge grew. In a small group with a few people, maintaining one’s own mental model of organizational knowledge was not difficult since everyone is either well connected already or interacts often enough through the venues and tools that updates to the models can happen regularly. As communities grow larger and consequently less well-connected, it becomes less likely that people will have frequent enough interactions with others to keep pace with their changing expertise. Scott explained how for him, it was easy to, “*keep track of a few people because I interact with them a lot. But let’s say this group expanded [to] 20 people. It would be extremely hard*.” This was further complicated by how quickly people’s expertise would change as they developed the skills to address the needs that surfaced as their research progressed. In our setting, students over a single academic term would develop design arguments for their research prototypes, learn how to build the system, and design and run studies on their systems, at each step gaining new skills and expertise. Moreover, students reported being hesitant to take the time to learn this information if it was not easy to assess. Alex recalled a term when he was a senior member of the community and was working on a paper, stating, “*[I] didn’t really feel like I had*

time to go to an undergraduate for help on a very research-y question when I didn't have enough time to figure out if they actually knew it, versus going to [grad student] who's always sitting [in the lab space] and just asking [them]." Vanessa, another senior member of the community, shared similar feelings, stating, "it would almost save me time to just go to help from the person I know who can help me rather than trying to explore and understand...how [peer] can help me." This suggests that while the snapshots of community expertise provided through the interactions occurring in venues and through the existing tools in the DTR community can help, they alone may not be enough to keep pace with the changing skill sets.

A further challenge results from the continual change in community membership. New members join the community each academic term, meaning that others in the community must now learn and monitor for their changing expertise. Scott commented on this, noting specifically that he would require recent interactions with newcomers to be able to learn their expertise: "And with all the people who are new to [the community], it's hard for me to keep track of their skills or the experiences unless I can talk to them during Pair Research and it's kind of recent." Issues are also created when experienced members of a community leave. Most students continue their research work until they graduate, moving towards centrality in the community as they develop expertise, form deep relationships with mentors and peers, and become mentors to newer students [24, 37]. However, upon graduation, this expertise and the connections they provided to their peers is lost, requiring people to find the lost knowledge elsewhere in the community. David recalled being in this situation as a newer student in DTR during his sophomore year, stating, "I knew certain people who I thought could help me with certain things, but since they graduated, you kind of have to find new people who can do that." This can result in a big loss of expertise in communities when the leaving members are the only ones who have deep knowledge on a topic (e.g., how to program with a specific stack or framework), requiring a community to find external resources to train its members on the topic or to wait for new members with knowledge on the topic to join the community.

5.3 Planning and Sequencing the Completion of Needs Across Multiple Supports

So far, we have seen how students in DTR monitored for the needs they have and determined where support in the network can be found. At this point, we would expect that the decision to solicit help should be relatively straightforward since the kind of help that is required and potential helpers are both known. However, even this process can be difficult since venues and peers are available at different times throughout the week, and are also sought out by other members of the community. Needs are often multi-faceted where interactions at multiple venues may be required to fully address a need. Moreover, the way in which a future interaction with the community is used could be dependent on prior interactions, so students may have to plan ahead for certain venues that are available less frequently (e.g., weekly Pair Research sessions with the full community versus an ad-hoc meeting with a single peer). An example of this was when Charlie was getting feedback on his Status Update presentation from a peer, but only after he had determined what he was going to present based on his meeting with his mentor.

To use the networked supports that are available at different times during the week and afford different kinds of feedback or activities, students had to adapt their needs to fit the venues that were available when they had a need. David shared his approach to doing this for office hours with a mentor or for a Pair Research session with a peer, stating that, "...in office hours, you're thinking about theory and what type of theory applies to what you need to work on, and in Pair Research you're thinking about an actionable item [to get help on]." Adapting one's needs to the available venues allows students in the networked community to get support from a venue at nearly any time during the week and potentially even from multiple venues since so many are available. George

elaborates on this point, sharing how he thinks through the different venues available to him when he encounters a research need:

“And when [a research need] happens, my strategies are broad. Like if it’s near Studio time, then that’s a Pair Research topic. If it’s near office hours, then I go to Henry (the faculty mentor) with it. And then sometimes I just chat with Robert (the SIG head), either in person or on Slack.” -George, Undergraduate

Students also considered resource scarcity when deciding which venues, mentors, or peers to access for support. While many forms of support are available in the network, any one venue or person may have limited availability and not be able to help with all things a student needs help on (e.g., a faculty mentor’s office hours are shared between all students). To that end, students would try to facet their help-requests across multiple support opportunities in the network. One way this manifested, as Sophia and Vanessa shared, was to first try to resolve one’s needs using resource guides that did not require others’ time:

“I first reach out to non-human resources, whether that be learning modules or just thinking on my own.” -Sophia, Undergraduate

“There’s almost a hierarchy where, first, I’ll do it by myself with these different resource [guides], then see if I can go to get help from someone else.” -Vanessa, Undergraduate

When guides were insufficient to resolve needs, our participants described the process of navigating a “social hierarchy” in the community to access peers. Sophia and Vanessa, for example, would both first reach out to peers in their SIG, who know a significant amount about their project and work on projects in a similar domain. If that did not work or if they felt that they had, *“bothered them enough already recently,”* they would move to peers outside of their SIG that they were still close to. These strategies allowed students to spread their use of the available supports across the community. This afforded them more opportunities to collaborate with peers and seek support throughout a week, but also helped to reduce the overburdening of any individual venue or peer.

While we observed students generally using a wide range of supports, we also found cases where students were unable or unwilling to seek out specific peers due to their own social inhibitions. These were particularly pertinent when students wanted to reach out to someone they were not close to. As George and Sophia stated, this made them more hesitant to ask, especially if a significant amount of time was required to address their need:

“Even if I know someone has the perfect alignment of knowledge with what I want, there is going to be hesitation if I also don’t know the person. And you know, if I rarely talk to them, it’s just going to be a little harder to reach out. It’s like a social anxiety sort of thing.” -George, Undergraduate

“It seems kind of awkward to be like, hey, I know we’ve only exchanged hellos, and asking for an hour of your time to give me very detailed advice on this seems like overreaching. So it seems kind of rude even though I know it’s not within DTR. It’s kind of hard to get over that stigma.” -Sophia, Undergraduate

These findings suggest that, even when people have the knowledge about what venues or peers are most effective for their needs, they may still require additional scaffolds or support to help them reach out and make use of a broader community.

6 FINDINGS: HOW MENTORS COACH EFFECTIVE NETWORK ACCESS STRATEGIES

So far, we have seen that accessing support in a networked community like DTR is a complex process in which students continually monitor their needs, identify viable support opportunities in the network, and sequence the completion of their needs across multiple interactions. However, it

is unlikely that newcomers will be able to practice these *network access strategies* well on their own, and will require coaching to learn effective access strategies. While coaching is common in many work and learning settings, an important distinction in a networked community is that coaching goes beyond the project work (e.g., in our setting, feedback on research arguments), and includes understanding *how people are accessing networked supports during their working process* along with any obstacles (e.g., not knowing who can help with a need; discomfort in asking a peer they do not know well for help) that may prevent a student from using the support network effectively.

In this section, we present the practices involved in coaching effective access strategies:

- (1) **Monitoring for network access strategies:** mentors build awareness of the network access strategies students are using.
- (2) **Scaffolding the practice of more effective network access strategies:** mentors help students develop and practice more effective strategies.
- (3) **Involving the entire community in coaching:** students in the community also take a role in providing coaching for network access strategies, in addition to the support they already provide for their peers' research needs.

We detail how mentors in DTR carry out each of these practices, and discuss the challenges that can hinder the coaching of effective network access strategies.

6.1 Monitoring For Network Access Strategies

Mentors in networked communities monitor students' networked access strategies to understand how they are working within the community and in what ways they can be more effective in using the network to support their needs. Monitoring for these strategies requires mentors to assess how people are working both in venues the mentor is present, and in those they are not. Mentors also need to understand why ineffective access strategies are occurring so that effective strategies can be suggested and practiced during the follow-up interactions they have with their students.

Ineffective strategies were frequently raised to mentors by students in the venues that they both attended. An important venue was the weekly SIG meeting, where mentors were given insight into what their students were currently working on, what they planned to do next, and if they were stuck on anything. This presented them an opportunity to understand what support from the network might be helpful for the student immediately, and what they would require in the near future. For instance, one of Robert's students came into a SIG meeting and shared that they wanted to write an undergraduate research grant. After Robert and Henry—the faculty mentor—pointed them to a resource guide on the process of writing the grant, Robert shared how he would, *“check the guide on my own around that same day in order to have a mental picture [of what comes next],”* informing him about what kinds of support might be useful for his students in near future, such as a meeting with someone who has written a grant before, feedback on a draft, and a meeting with him and Henry to discuss the draft further.

Once informed of the things students were working on or struggling with, mentors would check-in with their students on progress towards resolving their needs during subsequent interactions at other venues. For example, Laura shared how she would check-in with a student of hers who was struggling with presenting takeaways from a recent user test in preparation for writing a paper during follow-up interactions, and ask how he would plan to use future venues:

“I would check-in with him just to see, whether it was in our own office hours or in SIG, ‘Okay, so what were you planning to work on in office hours this week?’ Or, ‘What were you able to work on last week and where are you at right now?’” -Laura, SIG head

Mentors would also try to understand what was preventing their students from practicing effective access strategies. For example, Yousef recalled how one of his students during their first

academic term in the community mentioned how he would struggle with getting help when he would get busy or overwhelmed by the research work. Yousef saw how this was preventing him from getting a tech demo working since he was getting overwhelmed with the development work. To resolve the issue, Yousef worked with his student on strategies for setting up intermediate milestones and thinking about when and where his student could get support for the development process, such as from Yousef himself or from his peers who had worked on similar systems before. As another example, Nancy explained how she had previously noticed that one of her students on a project team would struggle to make technical contributions to their project. In a later reflection meeting with the student, she realized it was a fear of him contributing to the tech on his project that was affecting his ability to collaborate with his teammate, stating, *“I didn’t know that was a metablocker until he brought it up at the end-of-term exit interview, but then that gets added into my mental model.”* Moving forward, she would remember to ask him and his teammate how they were collaborating on tech-related tasks if she saw them in their Sprint Planning Tool, and how the struggling student could get help from his teammate or others in the community if needed:

“I would ask how are you guys sharing the load of tech? [Undergraduate], do you feel like you are pushing yourself to learn the parts of this that you want to learn? Do you feel like you’re asking for help at times where you’re getting stuck? What are resources you can use?” -Nancy, Faculty mentor

Mentors also had to understand how their students were accessing support throughout the week when the mentor was not present. One way mentors did this was by the absence of check-ins, especially when their students had planned to check in with them. While this did not directly inform mentors of what the student might be struggling with, it provided enough of a signal to suggest that their student may need additional support. Yousef said, *“when they don’t send me stuff that they were supposed to send, then I don’t know exactly what the issue is, but I can sense, ‘Okay, something’s going wrong.’”* Robert shared a similar approach, where he thought it might be a good time to check-in when his students were not asking for face-to-face meetings to discuss progress or issues, stating, *“If those aren’t happening, I at least have an awareness that there might need to be some type of intervention or to be able to check in [to see] what exactly is happening.”*

In some venues, mentors would not directly interact with their students but were still provided some visibility into how their students were using the venue. An example of this is Pair Research during the community’s weekly Studio meeting, which mentors do not always participate in. Yousef mentioned how he and his student who had been struggling with deploying his tech prototype had discussed ways to ask peers in the community for help, with Pair Research being one potential venue that would be effective. However, he instead saw that the student was using the venue to work on his research arguments instead of tech like they had discussed previously, indicating to Yousef that the student was still struggling to get help for tech development.

“During Pair Research I would expect him to say, ‘Oh, help me deploy this app to a phone’. But he’s always, ‘Oh, help me scope my obstacles, help me revise my outcome.’ So from there I could kind of see, ‘Okay, he’s not working on the tech.’ -Yousef, SIG head

In short, we see that mentors developed strategies for building the necessary awareness of their students’ access strategies across the venues in the DTR community to identify when coaching for alternative strategies for their needs would be useful.

6.1.1 Challenges in Monitoring For Network Access Strategies. Despite these practices, mentors still lacked visibility into the network access strategies that students were using because the students would have multiple interactions across a variety of venues that the mentor was not present in throughout the week. This makes it difficult for any single mentor to have awareness of the access

strategies a student is using. In venues where mentors are present, they are generally able to learn when different strategies are being used, as our earlier analysis has shown. But outside of these venues, it is not always clear how the student is working on their own. As Laura described:

“I don’t have much insight into that at all. I do in the sense that I think the way he brings up his plans in the times where I do get to interact with him in SIG meetings or in-office hours are probably not very different from how he’s thinking about working...But maybe he didn’t [work like that]—like the example of over working and like not talking about it in a SIG meeting.” -Laura, SIG head

As another example, Yousef shared a situation where he and his student had agreed on the goal for a study design, and a plan to prepare it. However, the student realized that an obstacle may prevent the agreed upon goal from being reached. Instead of scheduling an ad-hoc meeting with their mentor or attending another venue that could have helped to overcome the obstacle, the student started to think about other unrelated goals. Yousef mentioned that he did not know this was happening until the next time they meet, which prevented him from helping the student learn effective strategies to resolve their needs through the network when they occur:

“So they start having all of these like contingency plans...I don’t know if that’s useful because now you’re diverting. So when those kinds of things happen, I can’t know until we meet next time.” -Yousef, SIG head

This suggests that mentors in networked communities may need additional support for gaining awareness of how their students are using networked support in order to coach access strategies.

6.2 Scaffolding the Practice of More Effective Network Access Strategies

As ineffective network access strategies become apparent to mentors, they help their students practice effective access strategies for future interactions involving the network. This process is in addition to the coaching mentors provide to help students better understand the research work itself, and is focused specifically on helping them understand how to effectively seek out support from venues, tools, resources, and peers. In what follows, we focus on three aspects of effective network access that mentors coach on, which include: (1) suggesting ways to prepare to use a venue; (2) considering which venue is more appropriate for a need that students may have; and (3) encouraging students to get support from a broad range of venues and people in the community.

As students would surface what venues they planned to seek support from, mentors would coach them on how to actually use the venue well for their needs. This is important since the many venues present in the network afford different forms of support or activities that students may not necessarily know how to tailor their needs to, such as by coming in with broad needs that they cannot get useful support on during the limited time available in the venue [25]. In one example of how this is coached, Yousef discussed how he had a student that would frequently ask for his help on iPhone application development issues, but often without doing a set of common debugging steps prior to reaching out. Together, they developed a checklist of tasks that the student could try on their own before reaching out, or use to facilitate their discussions:

“So basically we ended up having some kind of checklist to go through. But maybe even if there’s a checklist, sometimes they don’t really follow and there might be some other problems that we didn’t catch with the checklist. So like we just go through each of the steps...Is it working on the simulator? It’s not. Okay, why is it not? Let’s go through it. Where should you put the debugging point? What are the components that are related to this task?” -Yousef, SIG head

Mentors also coached their students on strategies for selecting which venues may be more appropriate for the needs they have. For example, Henry recalled how one of his students was struggling with planning out a Status Update for the week. She originally wanted to use the opportunity to get feedback on her research arguments, but Henry mentioned to her that this really was not a great use of the venue, saying, *“And I thought, you can get feedback on design arguments from your SIG or from your mentors. And it wasn’t clear to me she really needed a whole class to do that.”* In particular, Henry was surfacing here how the Status Update venue is useful for activities where an entire community can provide useful insight, whereas the office hours or SIG venues are better for activities where the help from one or two people is sufficient, such as for research arguments. As another example, Laura detailed how she noticed one of her students struggling with the planning process and using the Sprint Planning Tool during their weekly SIG meetings. Rather than discuss this further during the SIG meeting, she instead, *“asked him to talk to his [onboarding mentor] and he was able to set up a couple meetings with [them],”* since using that venue was better than spending the limited amount of time she has with him during the SIG meeting.

During the process of helping students identify venues, mentors also coached their students on how to use support from across the network, rather than relying on a single mentor or peer. This is especially important for newcomers to the community who may be overly reliant on experts for help and not use the rest of the community, which is problematic for networked communities where experts’ limited time and help-seeking venues have to be shared across a large number of people. The most common way to do this was to direct students to other venues, resource guides, or their peers that could support the student’s needs. In one example, Laura described how one of her students would frequently come to her for help first, but instead of answering all of his questions, she would route him to others in the community (in this case, to help him with measures for a study he was planning to run):

“One of the challenges that he’s facing in his research was if we’re trying to evaluate the effectiveness of [prototype], how do we know someone filled out [prototype] well? And I told him, ‘I’m gonna punt you because you can get that answer from other SIG heads...it’d be good help-seeking practice for you to do.’” -Laura, SIG head

Encouraging the use of the broader support network required mentors to know what students or resources from across the community could provide the kind of help the mentor’s students needed. In coaching students, Nancy thought about what supports would be most help to direct students to based on their needs and her understanding of what other students in the community have done:

“One thing that’s really helpful is having a pretty good understanding of the other projects and what other students have worked on. So I definitely will point to students like, ‘Oh these other people I know have done this in their project recently, and they might not be in this SIG but you should talk to them because they’re an expert at that.’” -Nancy, Faculty mentor

Mentors also considered the context in which they observed a student’s expertise since that indicated to them if the student could help their student. For example, Yousef walked through how he would recommend help for issues related to the deployment of iPhone applications based on if they had worked on iPhone development at all, and if they had done it within the DTR community since he knew that everyone who deployed applications in the community used the same approach. With these two pieces of contextual knowledge, he said that he could recommend people for help related to iPhone deployment issues simply by knowing, *“if there was anyone who has ever worked on [iOS], then they know [how to resolve the need].”*

In situations where mentors did not already know who in the community or what resources would be viable for their students’ needs, they would attempt to use tools in the community as

knowledge repositories [8] to identify who or what could provide support. The community's Slack team was one tool used for this, which had channels structured thematically around different activities (e.g., office hours) and kinds of needs (e.g., help with code debugging; help with research arguments) that mentors could browse to find information relevant to their students' needs. For example when his students encountered a software bug, Robert would scroll through #proj-ce-tech, a Slack channel dedicated to discussions around his SIG's shared codebase, to recall debugging steps that he and his students had previously used to deal with similar bugs: *"I often scroll back through Slack...looking for a particular conversation we had...what was the doc I sent her? Or, what was the ordering of things we were talking about?"* Gary used a similar approach to understand what expertise community members had by looking through a channel called #learning-modules where students post images of their whiteboards after office hours or coaching sessions: *"I iterate through the members of the learning modules Slack channel because that's the best channel for gauging who actually is active in DTR right now, and I see, does this person have that expertise?"* This provided him information about what tasks (e.g., working on design arguments) each student had recently done, and what their level of expertise on that task might be.

6.2.1 Challenges in Scaffolding the Practice of More Effective Network Access Strategies. Despite having strategies for coaching on effective network access strategies, mentors lacked visibility into if and how students were practicing strategies that their mentors had suggested, and of any obstacles that hindered access. As we saw earlier, mentors struggled to see the access strategies that students were using outside of the interactions they had with students at venues mentors attended. In the same vein, this limited visibility also prevents mentors from seeing whether newly suggested strategies are actually being used. For example, Nancy shared how she may suggest a person that can help a student with a task and see them add the task to their Sprint Planning Tool, but, *"doesn't have any visibility of whether they did that, when they did that, if they did that before the task that was really dependent on having talked to [grad student]."*

Mentors also struggled to keep track of their students' access strategies, especially across weeks. This happens because of the multitude of strategies that mentors have to track about how their students are using network support, in addition to how they are thinking about their research work. Laura and Henry both highlighted how it's, *"just really hard"*, to be able to track how students are practicing all these skills on their own, with Henry further stating, *"there's a lot that goes on in the same meeting and it's a lot for a mentor to keep track of especially if you want to think about helping the student grow from week to week."* Nancy expanded on this further, describing how she had to maintain, *"each project needs, what's the riskiest risk of that project, and how do you give them feedback to push the project,"* and then quickly use that information in a way that helps them learn how to progress their work, but also how to use the network of supports in the process.

As a way to help maintain information about students' projects and needs, mentors began taking SOAP notes during SIG meetings with their students. SOAP notes—a homonymous method of documentation used by healthcare providers [13, 57]—capture the *subjective* information surfaced by the student (S), *objective* observations about the student's work or learning process (O), the mentor's *assessment* of what support the student requires (A), and *plans for follow-up* with opportunities for further interactions at other community venues (P). As Henry described, SOAP notes enabled mentors to capture, *"what each student's development is, and what are things that students kind of needed to work on for the project but also for the personal growth,"* across the research work they are doing and how they are practicing network access strategies. Skimming these notes enabled mentors to remind themselves what was discussed during previous meetings. Laura detailed how this was useful in subsequent meetings, *"to make sure that [her and her students] were still carrying the same narrative thread of these are the things, like these are the goals, this is the progress that we*

want to make,” especially in meetings where Henry, the faculty mentor, was not going to be present. This finding suggests that the development of tools for helping mentors track interactions with their students over time may be a necessary component to include in networked communities. However, the current instantiation of SOAP notes only capture the strategies surfaced to mentors in the settings where the mentors themselves are present, and not the many strategies that students might be using during their interactions with other venues in the community. As we will discuss more later, the design of tools to support networked orchestration will need to be aware of interactions occurring across the entire community if they are to be effective.

6.3 Involving the Entire Community in Coaching

Thus far, we have seen that mentors in DTR provide not only coaching for students on their work but also on their network access strategies. However, our findings also suggest that the students in the community could also provide coaching on network access strategies.

One way we saw this happen during our study was ad-hoc coaching interactions between students when one saw the other was struggling with using the other venues and resources in the community. In one instance, Christina helped Adam make sense of the feedback he was receiving at a SIG meeting about his Status Update plan that she happened to be attending to collect data for her own project. Afterwards, she and Adam discussed how to revise his research plan based on the feedback, and other ways to get support for developing his Status Update plan from the community. Adam found the discussion helpful, and stated, *“So that was actually kind of helpful because she was there to support me with slicing and scaffolding and just preparing a Status Update.”*

Another way students provided coaching was when they served as *onboarding mentors*: senior students in the community that helped newcomers in onboarding into the community. Onboarding mentors supported new students in learning the tools and ways of working in the community, as we saw with how Laura deferred her student to their onboarding mentor to learn about how to make research plans and use the planning tools. They also served as a bridge between new students and others in the community who may have expertise for a need the new student has. While we have shown that students do learn these overtime, a well-connected onboarding mentor can much more quickly resolve these gaps for new students, as Vanessa described when her mentor connected her with a graduate student who had experience in qualitative research:

“[Onboarding mentor] is actually the one who helped me branch out a lot... I was like, “I need help on qualitative coding because I don’t really know what that entails, who do you think I could go to to get help?” and [onboarding mentor] was like, “Oh [grad student] is super knowledgeable about this” and I think it was my first experience reaching out to that set of people.” -Vanessa, Undergraduate

These findings show the potential efficacy in growing the ability of a community to provide coaching on how to access in addition to the support or peoples’ needs that they already provide, rather than relying only on mentors for this coaching.

7 DISCUSSION AND DESIGN IMPLICATIONS

We have presented the complex working processes involved in networked orchestration for a research community of practice. In this section, we first discuss our findings and what they mean for future networked workplaces and learning communities. Then, we outline two design implications for future *networked orchestration technologies* that can assist members of a community in the process of learning the network access strategies to be effective in networked communities.

7.1 Discussion

7.1.1 Process of Accessing Support in a Network. Our analysis revealed that the process of accessing support in a network involves continually monitoring for needs, identifying where support in the community for the need can be found, and resolving a need across multiple interactions in the network. These findings show that simply providing access to venues, tools, and peers—something CSCW has heavily focused on—is not enough for people to be successful in a networked work or learning community. Instead, we need to understand the work that unpins effective practices that people use when working in these communities, what challenges they have as a result of them, and how we design technology to support the entire process of networked orchestration.

An important theme from our findings was how the venues and tools in the network played a role in providing the support they were designed to, and helping students learn effective ways of accessing the network. One way this happened was through Pair Research which provided peripheral or passive insight on people's tasks and potential expertise; another was through explicit coaching on access strategies that mentors provided to students during coaching sessions. Since supporting people in learning to access is crucial for them to be effective in a networked community [37], these findings suggest that future networked community should design venues and tools in their network that help develop people's access skills when they are used to address needs (e.g., venues that promote awareness of expertise [38, 52]; venues for coaching planning [39]), and consider creating new venues that support people in learning to access if they find the existing venues to be insufficient. Without this approach to the design of a community's venues and tools, learning to access support could be more challenging. Our findings also suggest an important cultural norm to foster in networked communities, where people view their interactions with the network as being in service of them learning effective access strategies for the future and not only to get support for their immediate needs. Finally, we believe that studying how the adoption of these venues and norms can enhance the learning of network access strategies is an important direction of future work as networked models of working and learning continue to be developed.

Despite these practices, we found that working in a networked community remains challenging due to the many parts of the accessing process that can go wrong. From our study, we found that students may (1) not realize their work or learning needs; (2) have difficulties in identifying potential venues that can provide support; and (3) have difficulties in accessing an opportunity even if it is known due to an unfamiliarity with the venue or person. Even though our findings show that members of this community were willing to access and work in a networked way (e.g., using multiple venues; reaching out to peers; etc.), we also see how the challenges of working in a networked setting—such as difficulty in tracking the changing expertise, even in a 20-person community—can hinder their ability to access support. While some of these challenges can in part be addressed by existing technology (e.g., tools for tracking and finding expertise in organizations [10, 11, 40, 41]), we lack the tools that help people think about the entire process of accessing a network of support (i.e., in identifying needs, planning support interactions, and sequencing interactions) and where access challenges may arise. These tools are necessary for learning network access strategies since the complexity in accessing a network of supports resides in the entire process of planning and replanning that is constantly being done as needs arise and attempted to be addressed. Without tools that explicitly help learners think about how to use different venues and tools, it becomes difficult for them to learn how the network can be used in different ways to support their needs.

7.1.2 Coaching Effective Network Access Strategies. Our findings also showed that the coaching mentors provided for learning network access strategies—beyond the coaching they already provided on the research work itself—required them to monitor for how their students were currently accessing support in the network and then scaffolding the practice of effective access strategies.

Some of these strategies included suggesting ways to prepare for a venue, considering the trade-offs between using different venues for the same need, and encouraging students to seek support from the network at large rather than only those they are close to (e.g., in our study, their mentor and peers in their SIG). These findings show that the coaching task for mentors in networked orchestration is an inherently much harder task than the already difficult task of coaching for project since—in addition to coaching for the project—they must also continually monitor for how their students are working in the network and scaffold ways to practice effective strategies.

We also found that the coaching itself became distributed throughout the community. As students spent more time in the community, their practice of network access strategies would mature and enable them to coach each other on how to access networked support. Further, these students were able to support newcomers to the community in learning networked ways of working through the onboarding program in our study. Through onboarding programs are common in many workplaces, they focus more on acclimating newcomers to the tools and broad processes of the organization (e.g., stand meetings in an Agile team), but not on helping them learn the ways of working and the network access strategies needed in a networked community. While mentors are able to provide this kind of coaching already, enabling the community as a whole to coach one another can be an effective way to help people learn access strategies without putting the sole responsibility of providing coaching on the mentors. We believe this is vital for networked communities to pursue if they aim to be sustainable as they grow—given the already difficult coaching task that mentors have—and that future work may consider studying how networked communities can integrate practices that help its members develop the skills to provide this coaching to their peers.

Providing coaching in a networked community is still challenging. From our study, we saw that mentors struggled with students' access strategies often being invisible to them, and with the difficulty in tracking the many skills that they are working on with each of their students over time. Without awareness of how students are working in the network, it becomes difficult for mentors to scaffold the practice of effective access strategies. While existing technology can provide awareness of a student's needs in a single venue (e.g., in the classroom [16, 26, 28, 55]) and even construct activities that can be done in those venues once the needs are known [17, 23, 36, 42, 59], these technologies lack the ability to provide an ecosystem level view into how a student is working across the network and to scaffold the practice of access strategies that in venues where the mentor is not present. Without tools that consider how people are working across an ecosystem, mentors will always have an incomplete picture of the access strategies their students are using and will struggle to coach ones that help their students work and learn effectively in networked communities.

7.2 Design Implications for Networked Orchestration Technologies

In summary, our analysis shows that for students to develop effective network access strategies (and accordingly, for mentors to support that development), we must move away from designing systems for an individual person accessing or using a specific venue—like those used in the ARS model and also a large focus in CSCW—and towards systems for learning access strategies that involve the entire socio-technical ecosystem present within a work or learning community. Instead, we require technology that has an *ecosystem-level view of interactions occurring across the venues and tools in a community* in order to support the development and practice of network access skills to work effectively in networked communities [49]. In the rest of this section, we discuss two directions for future work on *networked orchestration technologies* that aim to assist members of a community in the process of learning to access support opportunities in a networked community based on the challenges highlighted above. These include systems for (1) supporting the learning of network access strategies; and (2) supporting the coaching of network access strategies.

7.2.1 Tools for Supporting the Learning of Network Access Strategies. We lack tools that promote discussions about how different network resources can be involved in addressing one's needs over the course of a week. Tools for project planning (e.g., Asana [1]; Jira [3]; Trello [7]; Sprint Planning Tool in ARS) can track tasks and deliverables, but are disconnected from the networked ways of working that we have seen are needed to be effective (e.g., discussing how different parts of a need can be addressed through different venues). Not being able to plan out these strategies in advance precludes any fruitful discussions about access challenges that could be resolved with the mentor's help during planning meetings (e.g., not reaching out to a peer due to social inhibitions).

To that end, we envision future *orchestration planning tools* that help visualize the planning process by having students plan their tasks and deliverables using a diagram of the community's network (such as Figure 1). For example, we imagine that students like Charlie from our study could use the tool to plan out the preparation of his Status Update with the different needs involved (e.g., determining a plan; creating the Status Update activity); the venues where he would get support for those needs (e.g., his mentor; peers during Pair Research); and adjusting his plan as necessary (e.g., when Yousef helped him realize what he actually should do plan his Status Update). We believe such a tool would help students in learning how to approach the different needs that they have with support from the network, and also how to replan their working process as new needs arise.

Having tools that help students describe the ways they plan to and are using the network can also help other students in learning ways of accessing support in the network. Our study showed that students were already coaching one another on how to access network support, in addition to helping peers with their research needs. By visualizing the strategies each other is using from the entire community, students would be able to adopt strategies their peers are using to address work or learning needs similar to their own. To that end, we envision that orchestration planning tools could be extended to track the strategies that people are using *globally* throughout the community, which could then be discussed as potential working "templates" for common needs in the community (e.g., from our study, preparing a Status Update presentation, a research grant, or a paper draft). In this way, we believe that the orchestration planning tool can both serve as a way to support the process of access and for learning how to access the network more effectively, like the dual role that many of the existing affordances in the community already serve.

While we believe tracking and discussing student's access strategies could serve as a useful teaching tool, sharing these strategies could make students uncomfortable. For instance, a student may not want to share an example of how they worked ineffectively on a need, even if it would be useful to discuss with others as a post-mortem on how not to approach a similar need. While the data in aggregate could be anonymized, the highly contextual nature of some of the access strategies makes it more difficult to understand the decisions involved in the strategy if the context of the needs or project (which could link back to a specific student) are removed. To that end, we recommend that any system that tracks and shows a student's working strategies should be opt-in where a student can choose if they want to share their process of working on a need with others.

7.2.2 Tools for Supporting the Coaching of Network Access Strategies. We lack tools that are able to provide mentors with a more complete view of the interactions their students are having with venues, tools, and peers across the network, and scaffold the practice of network access strategies in venues the mentors are not present. Many project tracking tools (e.g., Asana [1]; Jira [3]; Trello [7]) already provide views into the status of tasks on different parts of a larger project (e.g., all tasks; who is working on what; what is or is not completed; etc.), but not the process of how people are working on those tasks that we need to understand network access strategies. In addition, many existing tools based on trigger-action programming (e.g., IFTTT and Github issues [2]; Slack Workflows [6]) are already able to react to simple situations (e.g., when someone files a bug report;

when someone joins the Slack team) to orchestrate follow-up actions that can involve other people or tools (e.g., inform the project manager to discuss the bug with the engineers; introduce new members to team's channels), but these tools are limited in how well they can orchestrate those activities in a networked setting where the activities are tied to different venues. Addressing this problem requires tools that are imbued with an ecosystem-level awareness of the structure of a community, when venues occur, what kinds of activities are appropriate in those venues, and the access strategies people use across the network.

Towards this goal, we envision future work on an *orchestration scripting system* that instruments the venues and tools in a networked community to collect observable data about people's interactions from across the network, uses those data to provide mentors awareness into the different access strategies being used, and scaffolds the practice of mentor-suggested strategies in venues where they are appropriate. For example, a mentor may want students to form feasible research plans each week, and write a script that detects when they have spent significantly more time on their research tasks than allocated. This could be done by checking their Sprint Planning Tool for how much time was planned and how much was actually spent. If detected, the system could alert the mentor during a coaching session to discuss with the student to understand why this is happening and suggest strategies to attempt in the future. Even further, the mentor could encode some common strategies directly into the script—such as having the student work through a resource guide that helps them reflect on why their research plan took much more time than planned—that the system could suggest to the student right away [17, 23, 36, 42, 59]. In this way, the orchestration scripting system can provide awareness of how network access strategies are being practiced and also begin to scaffold the practice of the strategies in venues throughout the network.

Mentors also require tools that provide them with a more comprehensive understanding of their student's access strategies across the network during coaching sessions with their students, and ways to support the practice of a strategy across venues in the network where they are applicable. To realize this, future work may consider an *interactive SOAP notes tool* that shows mentors the triggered orchestration scripts which occurred in venues throughout the week. Mentors can then use the tool to discuss the issues with their students and suggest plans for follow-up, similar to how SOAP notes were used by mentors in our study. Even further, we envision this tool providing mentors with common strategies that are already encoded and tracked by the orchestration scripting system which they could suggest to their students to attempt in the following week. As an example from our study, Nancy, the faculty mentor, could use this tool to have on-going check-ins with her students when they are working on tech-related tasks to ensure that the student who was weaker in tech received support to develop his tech skills. If she saw that her student was not getting enough support, she could write a script in the SOAP note tool that prompts the student to reach out to a peer for a pair programming session, and check-in with the student on how that went in the following week's coaching session. In this way, interactive SOAP notes help to provide coaches with an ecosystem level understanding of how their students are working, and a way to extend coaching to venues throughout the week where new strategies can be enacted.

Though we believe tools that are able to surface and support working practices across a network are needed, designers of these systems will need to consider the ethics of tracking students' working patterns. With the outlined approach, data to detect access strategies comes from instrumenting the venues and tools in the network, but this data is necessarily tied to individual students. One way in which this could be problematic is if the data is used for tracking when students are not working (such as in the evening or on weekends), and leading to them being seen as lazy by their mentors. To that end, we recommend that these systems only use the data that is readily available (e.g., from our study: Sprint Planning Tool; Pair Research; Research Canvases; attendance at venues; etc.) rather than trying to instrument every form of interaction occurring in the network (e.g., edit

history of documents; messages between community members). In addition, every community member should be allowed to review what data is being tracked for them, and give permission for the system to include it and who can view it (or revoke permission in the future).

7.3 Limitations and Future Work

Our work has two limitations that future work should consider. First, we have only studied the processes and practices used by one networked community in one domain when accessing a network of support. We chose to study this community due to the maturity of its network. However, a community can create or instantiate a network in many ways to tailor the network to different kinds of work (e.g., makerspaces [30]). The composition of the community itself as it relates to the diversity of demographic, gender ratio, cultural norms, etc. may also have an effect on how the community orchestrates its work and learning [15]. In addition, many teams have moved away from co-located offices and towards remote work distributed around the world which can create further challenges for collaboration [54, 61]. Because of this, future work may consider studying organizations that have different network structures, social configurations, or norms, or work in different domains to understand how access patterns or the process of learning to access may differ.

Second, our analysis was focused on understanding monitoring, planning, and replanning skills involved in accessing networked supports. While these skills are important, people may also struggle to develop the socio-emotional skills necessary for accessing a network of support, such as becoming more comfortable with reaching out to unfamiliar peers that are viable helpers for a need. Lacking these skills can hinder how well a person is able to enact effective access strategies and address their needs [33]. To that end, future work may consider studying the different socio-emotional mindsets (e.g., help-seeking; growth mindset [18]) necessary for working in networked communities, and the kinds of support required to help people develop them.

8 CONCLUSION

As work and learning communities continue to adopt socio-technical ecosystems to assist their members in working on complex problems, we must understand *how people access and learn to access support* in these communities, and the coaching required to help them do this effectively. Our analysis of networked orchestration in an undergraduate research community unveils the myriad of network access strategies that students use to get support from multiple venues and peers throughout the week; the coaching mentors provide them on effective access strategies; and the challenges that students and mentors face that hinder their ability to access and learn to access support effectively. While tools for providing access remain effective, we lack tools that support the process of learning to access network support. In particular, our approach to developing tools for these communities has largely focused on the provision of access or the support of an individual in a single venue. If learning to access is truly what is most important in these networked communities, then we must instead move towards developing ecosystem-level tools that support the process of learning to access across a network of venues, tools, resources, and peers. We envision that these networked orchestration technologies will be crucial for fostering the networked ways of working and learning that are becoming prevalent in our workplaces and learning communities.

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A DETAILS OF INTERVIEW PARTICIPANTS

Table 1. Participant information for all interviewed community members (all names are pseudonyms). Kyle was not interviewed in the study as he was the interviewer and observer during the study.

Name	Role	Academic Terms in Community	SIG Research Domain(s)	SIG Research Focus
Henry	Faculty	17	Social computing, Crowdsourcing, Learning sciences, Computing education	<i>Sits in on Laura, Robert, Kyle, and Gary's SIGs</i>
Nancy	Faculty	6	Learning sciences, Computing education	<i>Sits in on Gary's SIG</i>
Yousef	SIG Head	16	Crowdsourcing	Systems for coordinating real-world crowds
Charlie	Undergraduate	2		
Adam	Undergraduate	1		
Laura	SIG Head	10	Learning sciences	Systems for community supported learning
Vanessa	Undergraduate	3		
Scott	Undergraduate	2		
Robert	SIG Head	7	Social computing	Systems for building social connection
George	Undergraduate	3		
Kyle*	SIG Head	4	Social computing	Interaction techniques for collaboration
Alex	Undergraduate	3		
Christina	Undergraduate	2		
Jason	Undergraduate	2		
Ronald	Undergraduate	1		
Gary	SIG Head	4	Computing education	End-user programming tools
Melissa	Undergraduate	5		
David	Undergraduate	4		
Sophia	Undergraduate	3		
Susan	Undergraduate	1		

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