The situational window for boundary-spanning infrastructure professions: Making sense of cyberinfrastructure emergence

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In the twenty-first century, professions are complex and difficult to define due to their fluid and interdisciplinary natures. In this study, we examined the personal career stories of professionals in the field of cyberinfrastructure (CI) to identify the narrative patterns used to make sense of CI as a boundary-spanning profession. Overall, we found that professionalization of CI is a sense-making process of communal, retrospective storytelling. The meaning-making of CI as a profession occurred through three levels of narrative patterns: individual traits of CI professionals, situational introductions to CI, and inspirational convictions about CI. The situational level, which connected innate qualities and internal motivations with external forces to join CI as a career, was especially important to the professionalization of CI. Our findings have implications for re-examining professionalization as an ongoing sensemaking process, as well as offering guidance for recruitment and retention in critical boundary-spanning professions.

KEYWORDS: professionalization; sensemaking; boundary-spanning profession; emerging profession; infrastructure; cyberinfrastructure

In the twenty-first century, professions are complex concepts due to their interdisciplinary, boundary-spanning natures. A profession encompasses both a disciplinary field and a career path and has been defined as: ‘An occupation whose core element is work based upon the mastery of a complex body of knowledge and skills’ (Cruess, Johnston and Cruess 2004, p. 74). Professions involve distinct bodies of knowledge, such as in the cases of lawyers and doctors (Dingwall and Lewis 1983; Kuhn 2009). However, other more interdisciplinary professions in areas such as corporate social responsibility (Brès et al. 2019) and sustainability (Mitra andBuzzanell 2018) challenge clear boundaries and established professional characteristics. Such professions force scholars to expand the dimensions of professionalization to emphasize shared goals, expertise, and collaboration (Evetts 2002, 2003; Brès et al. 2019). Particularly in the fields of computer science and information technology, scholars and professionals have struggled to define what makes the fields distinct from other areas such as the physical and life sciences and engineering as well as the social sciences (Denning 2001, 2005). Twenty-first-century professions challenge scholarship to go beyond reliance on boundary markers—instead, as our article explores, professions emerge through fluid and continuous sensemaking processes. While sensemaking stories contain individual and inspirational qualities that might draw professionals to the technical duties of a profession, we find that the situational level of stories is especially important, involving setting details that establish the symbolic situation or context for individuals’ actions. Only through embedding individual and inspirational qualities into a symbolically meaningful and distinct situation will open the window of opportunity for a new, boundary-spanning profession to form.

In this article, we analysed interviews with cyberinfrastructure (CI) professionals to identify the narrative patterns that make sense of CI as a profession. Anteby et al. define occupations as ‘first and foremost social entities’ that include patterned behaviour, work category, a set of actors, and related societal structures (Anteby, Chan and DiBenigno 2016: 187). Scholars have examined the many layers of professions, impacted by sociopolitical forces...
as well as contributing to and springing from individuals’ sense of identity (Evetts 2003; Cheney and Ashcraft 2007; Lammers and Garcia 2009). Due to shifts in the professional landscape, such as digitalization and distrust of institutions, Carter et al. state ‘the death of professions has long been prophesized’ for our post-industrial world (Carter, Spence and Muzio 2015: 1208). However, professions continue to be shaped and reshaped within the institutional and individual forces of organizational structure and life. We explore how the very twenty-first-century community of CI engages in a professionalization process which spans bodies of knowledge through sense-making narratives, rather than the formal categorization that marked some previous profession scholarship.

CI is a network of supercomputing tools and technologies spread across the United States at different university campuses, such as the Texas Advanced Computing Center at the University of Texas at Austin, the San Diego Supercomputer Center at the University of California at San Diego, and the National Center for Supercomputing Applications at the University of Illinois, Urbana-Champaign. Across all campuses, CI is aimed at supporting the use of big data in scientific work. CI involves connection on a vast scale, with comparisons to the electricity grid and other critical public infrastructures. Through its connected nature, CI cultivates breakthroughs in knowledge and provides more computational power than previously considered possible (Stewart et al. 2010). Given that the CI community is self-organizing, CI’s professional identity is complex; the community is largely dispersed at various institutions across the United States and dependent on the funding and support of other organizations such as universities and governmental entities to function (Kee and Browning 2010). However, its complexity reflects the increasingly complicated nature of professional identity in the twenty-first century. While once professional organizations provided self-concept building blocks throughout an employee’s life, now such building blocks are spread across several overlapping organizations and dispersed locations (Lamb and Davidson 2005; Cheney, Christensen and Dailey 2013). Thus, examination of professional identity within the context of CI could shed light on how boundary-spanning professional identities are constructed within dispersed self-organizing communities as well as shedding light on how technologies impact such a construction.

Our work exploring how professionals use sensemaking processes to understand CI as a profession has several theoretical and practical implications. First, recontextualizing professionalization as a sensemaking process extends research grappling with the fluidity of twenty-first-century professions as well as the role of communication and discourse in professionalization (Bechky 2011; Mitra and Buzzanell 2018; Brès et al. 2019). Recontextualizing professionalization in this way captures more of how communication drives the ongoing, boundary-spanning nature of professions today. Second, CI as a field and innovation could be revolutionary for research and knowledge-building in the United States and beyond. When presenting the original vision of the technologies and community, the Atkins Report described CI as enabling a ‘digital revolution to serve the next generation of science and engineering research and education’ (Atkins et al. 2003: 4). The vision of CI involves a network of big data capabilities made accessible to all. The community’s vision can be compared to the aim of plumbing to make clean running water more accessible, or highways making travelling long distances easier, at least in ideals if not always in practice. Understanding the professionalization of CI could aid in ensuring that there will be effective future generations of professionals dedicated to supporting such a revolutionary technological system.

LITERATURE REVIEW

Beyond its technological focus, CI involves a human dimension, a ‘human infrastructure’ surrounded and supported by a wide variety of professionals dedicated to the practice of doing, enabling, and maintaining high-powered computational scientific work (Lee, Dourish and Mark 2006). In fact, ‘At the heart of the cyberinfrastructure vision is the development of a cultural community’, a group of people who get a sense of meaning and connection through being involved with CI (National Science Foundation Cyberinfrastructure Council 2007: i). CI professionals often assume many roles within the community and come from a wide range of backgrounds, including highly educated computer scientists, physical, life, and social scientists, and even individuals from the arts and humanities in addition to the more technically-oriented technologists and practitioners (Kee, Le and Jitkajornwanich 2021). However, despite such a wide scope, individuals within the CI community intentionally position themselves as CI professionals, their intellectual and technological space distinct from other fields (Berente et al. 2017).

The community of CI professionals has advocated for formal standards for their unique profession, in part to legitimize themselves to garner long-term federal funding and a stable workforce. Community members in CI, also called research computing and data (RCD) professionals, have described the challenges for CI workforce development, including those relating to human resources at institutions for workers within the new field, differences...
Professionalization
The term ‘profession’ is often used to describe established fields, signalling a legitimacy and importance in lay discourse about career paths. Professions connotate a level of importance and selectivity, such as in the professionalization of finance, which gave its included professionals higher social status than previously attainable within the field (Lounsbury 2002). Previous views on professions defined the term as spaces for exclusive bodies of knowledge, specific niches of shared technical expertise and formalized ethical standards (Brès et al. 2019). The development and perception of professions rely heavily on institutional logics, which can lend new fields such coveted legitimacy and structure (Scott 2008; Lammers and Garcia 2009; Garcia and Barbour 2018). Professions carry not only practical concerns, such as need for community, standards, and shared expertise, but also a symbolic level, contributing to individuals’ self-perceptions and social status as professionals (Kipping, Bühlmann and David 2019). In cultures that prioritize work experiences, such as the United States, professionalization remains a driving motivation in individuals’ pursuit of careers and social status.

Attention to professions in organizational scholarship has waxed and waned, as the new work environment of the twenty-first century challenges previous assumptions about what professionalization entails (Cheney and Ashcraft 2007). For instance, less boundaries exist between fields through increased emphasis on universal perspectives and challenges to notions of all-encompassing nation-states (Faulconbridge and Muzio 2012). Digitalization has muddled twenty-first-century professionalism due to opening access to specialized knowledge and questioning established notions of expertise (Walsh 2003; Švarc 2016; Stein 2019). In fact, Freidson suggests that the defining characteristic of a profession is the use of specialized knowledge to solve problems in a particular field. He also argues to notice the taken-for-granted assumptions about professions and membership and boundaries can get complex (Freidson 2001). Overall, Freidson’s idea about the activities that make up a field emphasizes the importance of specialized knowledge as well as the need to manage complex boundaries across existing professions and expertise.

However, professionalization continues to be an important quality for how individuals glean meaning from their work (Mitra and Buzzanell 2017). Although perhaps more dispersed and multidimensional, boundary-spanning professions still carry weight in the meaning professionals grant their career journeys and work tasks. Operating within the overlapping realms of computer science, engineering, scientific and academic research while involving many different bodies of knowledge, CI faces a challenge of defining its own distinctiveness and legitimacy as the community surrounding the tools continues to develop.

Sensemaking and professions
The professionalization process relies on communication for individuals to make meaning from their work and disciplinary fields. Bechky defined work occupations as ‘negotiated orders’, in which individuals must interact and communicate within existing institutional spaces to establish and change their professions (Bechky 2011: 1159). Several other organizational scholars have explored the role of communication in the meaning-making and legitimacy of professions. For instance, discourse played a central role in airline pilots and, more recently, sustainability practitioners defining their work tasks as a profession (Real and Putnam 2005; Ashcraft 2007; Mitra and Buzzanell 2018). Communication strategies represent the central way individuals conceptualize, reinforce, and promote professions, especially if the professions are fluid, emerging, and/or boundary-spanning.

Perceptions of legitimacy are one of the central meaning-making factors of professions and motivations for professionalizing a community. For instance, Garcia and Barbour found communication to be a key dimension of professionalization as librarians negotiated for increased legitimacy for their profession (Garcia and Barbour 2018). The situations of certain fields, especially if they are overlooked and converging with other established fields, such as CI, create a need for professionals to structure and communicate the meaning of their unique area of work. Sudday and Greenwood outlined such a communicative attempt at legitimacy through describing the rhetorical strategies used when an accounting firm purchased a law firm (Suddaby and Greenwood 2005). Professions do not arise or operate in isolation; a continual meaning-making
process must occur to create and support perceptions of legitimacy in work and career areas.

Furthermore, Wilensky (1964) claims that professions must persuade people of the ‘mystery of the craft’, an idea echoed by Garcia and Barbour that professions need to convey a sense of specialized knowledge and expertise to an external audience (Garcia and Barbour 2018). This process involves presenting their work as complex, sophisticated, and requiring a high level of skill and training that is not easily accessible to lay people. In other words, professionals need to create a sense of mystique around their work, emphasizing the importance of their specialized knowledge and the value of their services. This can help to establish their legitimacy and authority in the eyes of the public, and to differentiate themselves from other types of workers who may not have the same level of training or expertise. Wilensky’s claim as well as Garcia and Barbour’s work suggest that professions must effectively communicate the value and importance of their work to establish their legitimacy and secure their place in society.

One such way of communicating legitimacy for professionalization may be sensemaking, as the theory explains the role of communication in meaning making. Sensemaking is a communication process that involves individuals making sense of complex events and concepts. The work of Karl Weick first conceptualized sensemaking as a collective process focusing on retrospectively sorting out experiences (Weick 1995). Organizational scholars have considered the role of sensemaking in professions and professional identity. For instance, sensemaking is an essential process as professionals incorporate new technologies such as artificial intelligence tools into their work (Goto 2022). Others have found that sensemaking occurs as professionals navigate complexities in their established work processes, such as healthcare professionals attempting to treat patients with coexisting health issues (Sylvain and Lamothe 2012). Yet others have explored how professionals engage in sensemaking during confusing and/or crisis situations or complex situations, such as converging global markets (Cornelissen 2012; Kuznetsov and Kuznetsova 2014). Scholarship has not yet directly examined the idea we explore with this study, that professionalization and sensemaking are connected.

Sensemaking stories have particular features and patterns scholars can observe. Weick noted the sensemaking phases of bracketing and labelling, in which people notice and begin defining areas of complexity and change; enactment, in which communication of experience leads to meaning beginning to form; and selection and retention, in which possible meanings are narrowed down and remembered to guide present and future interpretations of events (Weick 1995). Further, scholars such as Andrew Brown have characterized sensemaking as specifically a storytelling process (Brown 2004; Brown, Stacey and Nandhakumar 2008). Within a professional context, the importance of collective storytelling also relates to Larry Browning’s theoretical framework of ‘lists and stories’. Browning articulates that organizational communication is not simply about technical rationality, such as logics and standards, but also narrative rationality, such as stories (Browning 1992). Browning’s framework can be used to highlight that professional motivations for joining a profession may seem technical in nature, when described using logics such as practical needs for the technologies and personal needs for specialized jobs. However, Browning’s argument is a call for organizational communication researchers to also include the narratives as a form of rationality, as they represent an important part of what truly captures professional realities. Thus, narratives play a large role in organizational life, potentially including professionalization. Narrative patterns, or evidence of storytelling structure, should be examined as fulfilling sensemaking functions within professional contexts.

Sensemaking narratives are not superficial but involve intimate meaning-making that impacts individuals’ sense of identity and community, reflecting the meaning that must be assigned to a profession. A large part of what qualifies a field as a profession involves the meaning the involved individuals assign it and how it contributes to their professional identities. Individuals cast themselves in certain narrative-bound roles to communicate and maintain their self-concept. Past scholarship on self-categorization theory has examined how individuals place themselves in categories to manage uncertainty (Turner and Reynolds 2011), and research on social identity theory has also noted how individuals sort themselves into certain categories to define themselves (Ashforth and Mael 1989). Scholars such as Scott et al. have used self-categorization theory to illuminate narrative framing, as stories involve situating individual narrators within larger events (Scott et al. 2018). Further, scholars such as Rasmussen have noted that narratives play an essential role in how organizational members establish and maintain their sense of self (Rasmussen 1996). The self-conceptualized status of a professional is largely constructed through communication, with the linguistic resource of the term ‘profession’ lending credibility to new occupations (Brès et al. 2019). Through involving meaning-making storytelling, sensemaking can help individuals conceptualize and articulate their complex identities as professionals.

Our study concerns the boundary-spanning profession of CI. In particular, we wanted to know how individuals
give a boundary-spanning discipline, field, and innovation the meaning of being considered a ‘profession.’ An organizational communication perspective could shed important light on how new professions emerge and become sustainable. For instance, Teodoro studied the emerging profession of policy entrepreneurs, uncovering important findings on governmental worker mobility and priorities impacting which and how innovations are adopted (Teodoro 2009). Scholars Flood and Robb examined how new technologies such as blockchain have led to occupational change, as lawyers and other established professions must adapt to changing circumstances and challenges (Flood and Robb 2018). New technologies impact professions and professionalization, as can further be seen with the developing profession involved with CI technological systems.

In the case of CI, multiple organizational entities such as universities and federal government agencies such as the NSF hold sway. Therefore, the diffusion of the more wide-reaching profession or ‘human infrastructure’ surrounding the complex, new technologies is essential to illuminate the link between twenty-first-century innovations and professionalization (Lee, Dourish and Mark 2006). The above literature led us to wonder why individuals decide to come to CI as a distinct profession. For this study, our research question (RQ) states:

**RQ:** What sensemaking narrative patterns do CI professionals use to describe joining the boundary-spanning CI profession?

Given this RQ, we sought to understand the formation and presentation of CI as a profession through CI professionals’ use of retrospective career stories. This angle also represents a unique research opportunity in organizational communication, as findings to the stated RQ can shed light on the unique professional context of blended domains (e.g., research IT, which bridges both IT and research in The Science, Technology, Engineering, and Mathematics [STEM]) as well as communication context of the boundary-spanning nature of CI.

**METHOD**

In this study, we examined interview data to explore how CI professionals describe their entrance into the boundary-spanning profession through coming to know CI. Examining the concept of identity within organizations, Ashforth and Mael conceptualized identities as continually made through the telling and retelling of narratives (Ashforth and Mael 1989). As cited in Cheney et al., scholars have conceptualized identity as ‘a storied self, a self that unfolds in the stories that we tell ourselves and in the accounts we provide to others about our past and present behavior’ (Dunne 1996; Rasmussen 1996; Cheney, Christensen and Dailey 2013: 697). We examined the career path narratives of CI professionals using a grounded theory approach to better understand how the CI profession emerged in the twenty-first century through the meaning-making and identity-shaping processes of individual professionals.

**Participants and procedures**

For this project, we used interview data from a study originally conducted to investigate the organizational capacity and capacity building for CI adoption (Kee and Schroek 2019). For the original project, the researchers sampled participants based on their familiarity with the rather specialized area of CI, whose job in some way involved directly using, developing, and/or maintaining the technological system (N = 132). The recruitment started with a list of interviewees (purposive), but the researchers asked participants to recommend others who were working in CI, eventually using a snowball recruitment technique (Johnson 1990; Sætre et al. 2007). The initial list of participants was compiled by looking up speakers of the 2015 and 2016 ‘Extreme Science and Engineering Discovery Environment’ (XSEDE) conferences. The XSEDE conferences underwent a name change in 2017 to ‘Practice and Experience in Advanced Research Computing’ (PEARC). We continued adding to the initial recruitment list by looking up speakers of the 2017 and 2018 PEARC conferences. The conference programs with speaker names were publicly available on the conference websites for XSEDE and PEARC.

The researchers conducted in-depth semi-structured interviews with the professionals either face-to-face at the conferences or through a phone call, between 2016 and 2019. Due to the timing of the study within the context of technological developments, our participants represent what we would characterize as the first generation of CI professionals; CI technologies first emerged in the early 2000s, becoming professionalized gradually through the 2010s and beyond. Although we had 132 participants in this study, the total number of transcripts was 181 since some of the participants were interviewed twice as a member check measure. The shortest interview was a little over 19 min, and the longest interview was 1 h and 40 min, averaging about 45.68 min each. Researchers conducted the second set of interviews to dig deeper into understanding what CI meant to them, their roles in the CI ecosystem, and their views on the future of CI. Twenty-four participants were female, and the rest were male, a distribution roughly equivalent to the gender
disparity in the CI community as a whole (Maimone et al. 2022). Each interview transcript was about 10 pages single-spaced, giving us approximately 1,810 pages of text to analyse. We received IRB approval for all stages of the study, including original data collection and the analysis carried out for this article.

Although the entire interview process was not focussed on generating narratives, during the interviews, the researchers asked participants to describe how they were first exposed to CI and what factors motivated them to enter the boundary-spanning field. This prompt was a strategy to provide personal context and warm-up for subsequent interview questions. This article is primarily based on participants’ responses to the warm-up question about their first exposure and entry into the CI field. More specifically, we asked participants to share with us ‘Tell me who you are, what you do, and how you got to where you are today’, and follow-up questions appropriate to their initial response to the prompt. A semi-structured approach for the interviews allowed a narrative unfolding of various factors and motivations for these CI professionals (Wengraf 2001). The goal of each interview was to identify the dimensions of organizations needed to support CI and to understand personal views on CI as a boundary-spanning field and career path. The initial prompt and follow-up questions generated the data that led to the current article.

To ensure confidentiality of participants, the transcripts included only the professional role, US state or country (if outside of the US) locations of work, and transcript numbers within the article to introduce excerpts. In the section below, we identify participants by a subject identifier for ‘professional’ (P) followed by a number in the order of their initial interview. Participants’ professional roles were diverse, including administrators who were the leaders and in-charge of managing a center/lab/CI project at various university campuses, technologists who built CI as developers, domain scientists (that we call ‘scientist–developers’) who develop and use their own CI tools, co-producers who are scientists and technologists that collaboratively co-develop CI, pure users who adopt pre-existing tools, and liaisons/facilitators who educate users about the CI resources. Most participants mentioned wearing multiple hats and serving multiple roles at the same time.

Data analysis: a grounded theory approach
For our qualitative analysis, we used a grounded theory approach that evolved throughout the data collection process (Corbin and Strauss 1990; Strauss and Corbin 1994). Our approach began with a thematic analysis of recurrence, repetition, and forcefulness on the data to find themes, organically allowing concepts to rise from the data without preconceived ideas and with aim of generating theory (Owen 1984; McCracken 1988). We used this thematic procedure to analyse all the transcripts and answer our study’s RQ.

We implemented open coding, and we generated themes through marking important phrases, statements, or passages using NVivo, a qualitative data analysis software (Bazeley and Jackson 2013). During the initial ‘open’ stage of coding, we identified themes such as ‘driven by science’, ‘acuity’, ‘rollercoasters’, ‘community of people’, ‘along the path’, and ‘moving through jobs’.

Second, moving into ‘selective’ and ‘axial’ coding, we analysed transcripts for logical relationships and transcripts were reread to confirm or collapse the relationships between codes. We combined themes as appropriate, for instance collapsing the then-separate ‘along the path’ and ‘moving through jobs’ themes that captured the timing and context of joining CI to create the ‘situational factors’ patterns we elaborate on in the next section.

Lastly, we sorted regrouped, and synthesized the generated themes into an overarching theme (selective coding). Once we had our individual, situational, and inspirational factors identified, we realized these corresponded with the basic ingredients of narratives, as explained by Jones et. al to include characters, setting, and plot or action (Jones, Shanahan and McBeth 2014). These elements were the narrative patterns that we focussed on in our findings, as described in the next section.

Moving towards the final step of grounded theory, we synthesized the identified patterns into an overarching theoretical concept, the idea that interdisciplinary, boundary-spanning professions such as CI emerge from sensemaking processes. Therefore, we used Corbin and Strauss’ open, axial, and selective coding stages to analyse the data, with the ultimate goal of developing theory (Corbin and Strauss 1990). We intentionally followed the stages and procedures of grounded theory, aiming to allow organic themes to arise from the data and then synthesizing those themes into a theoretical concept about professions formed through sensemaking. The sensemaking narrative patterns we identified in the analysis follow.

FINDINGS
Participants described entering the boundary-spanning CI profession through three narrative patterns: individual character roles of CI professionals, situational introductions to CI in logic- and symbol-bound settings, and inspirational convictions about CI that inspire professional action. As described in Table 1, individual factors involve what we summarize as the sentiment ‘I have what
it takes to be a CI professional’, situation factors involve ‘I met CI by accident’, and inspirational factors involve ‘CI is my calling’. Each of the patterns has specific qualities of CI’s sensemaking narratives, including the character roles of gadget geek and help desk guru, the settings of work’s necessity and student experience, and the inspirations of awe in systematic computing innovations and appreciation of interdisciplinary work.

Together, the patterns combine to represent a continual sensemaking process, as CI professionals attempt to establish and extend CI as a profession that overlaps a variety of disciplines. CI professionals perform the bracketing and labelling of sensemaking when recognizing gaps in established professional fields and articulating their own roles within those gaps. Finally, they perform the enactment phase of sensemaking when defining the unique situation and meaning of CI as a profession among converging disciplines. As with the work of Browning, we find that CI professionals use both logical lists, or technical rationalities, as well as symbolism and drama when explaining their workplaces, careers, and professions (Browning 1992). In other words, CI professionals described both practical needs driving CI, such as the need for technical experts in the new computational area of big data and a serendipitous sense of being impacted as students by authority figures and timely trends, as well as symbolic needs, such as the desire to innovate and expand knowledge.

Importantly, however, we find that all rationalities for joining CI involve sensemaking, a continual process of using narrative structure to sort out experiences (Weick 1995; Brown, Stacey and Nandhakumar 2008; Goto 2022). The narrative patterns we identified allow CI professionals to merge qualities of their personal identities with the technical markers of several other professions, creating a narrative universe in which CI’s professional significance feels comprehensible and necessary. Especially important to the sensemaking process are the situational factors: setting and background details in which the profession of CI can both overlap with and separate from other professions. In sensemaking terms, the situational is the level of narratives where enactment occurs. Where CI professionals situate the narrative of their CI career stories showcases that boundary-spanning professions can be understood through the distinct ways they converge with various disciplines.

The sensemaking process does not only explain individual motivations for CI professionals starting their careers; together, the narrative patterns showcase another way of understanding boundary-spanning professions. Our analysis of CI emphasizes that professions of the twenty-first century must be understood in their convergence with other fields. The convergence process happens within continual sensemaking narratives that are both rigid enough to provide professional structure while fluid enough to span disciplinary boundaries. Such a process is realized within the ‘situational level’ of retrospective narratives about the profession, setting elements involving the locations and backstory of the profession. With CI, professionalization is not a process of boundaries being defined and differentiated, but boundaries being continually overlapped in patterned ways. Our findings are explained below, offering the character, setting, and plot patterns layered upon one another in the sensemaking stories of CI professionals.

**Pattern 1. Individual factors: ‘I have what it takes to be a CI professional!’**

When participants described themselves as entering the field of CI, they implied self-categorized character roles
that uniquely drew them to the developing profession. The narrator roles we identified in the retrospective story of CI include the gadget geek and the help desk guru. Often, a combination of both roles contributed to the participants’ distinctive motivations to join the CI profession. The individual factors can be generally summed up, in our words, by ‘I have what it takes to be a CI professional!’ While incorporating technical rationalities such as a dedication to a new infrastructure and hopes for standardization, the character roles are narrative-bound labels in which CI professionals begin understanding their professional ‘place’, as will be described in the situational factors we explain later. We elaborate on the character roles below.

**Gadget geek**

The gadget geek individual factor refers to CI professionals’ love for technologies. The gadget geek is drawn to computers and other technologies from a natural curiosity. These individuals get their sense of professional and personal pride from their interest and participation in specialized communities dedicated to advancing computational technologies and the activity of programming. As an administrator, scientist-developer, and co-producing user from California self-described, ‘I am a nerd and, as all nerds, there’s a certain affinity towards gadgets and a certain affinity towards technology’ (P016). A scientist-developer from Ohio described entering the CI community after reading an article on ‘a geek news website’, sparking curiosity (P020). Another CI professional, an administrator, technologist, scientist-developer, and liaison/facilitator from Arkansas, said, ‘I have been a science geek since I could walk and talk’ (P049). Casting themselves as a geek, CI professionals perform a key feature of the CI identity: the innate drive to tinker with new technologies.

In addition, the gadget geek includes individuals who cannot quell their interest in computers and programming within another, single field. Their natural drive to learn more and more about technologies leads them to the edges of established areas of work and more standardized professional communities, instead finding kinship in the CI community with its dispersed, restless, and outside-the-box nature. For instance, an administrator, technologist, and liaison/facilitator from Idaho said:

> [M]y undergraduate degree was a business degree. So, on paper I at least, I have all these technical skills or whatever, but I have a business degree. So, ‘Well, here’s a geek that can talk to regular users.’ So, I don’t know if that’s true or not. So yeah, just having—developing those skills. If you’re a geek who’d rather sit and code all day, get out of your shell a little bit. Go talk to your co-workers. Go talk to users. (P053)

This individual described combining skills with technologies with a background in business, situating their role at the convergence of different disciplines. Rather than focusing on dominating a certain area of specialized knowledge, curiosity and love of learning propel CI professionals into other fields, which they then combine in their specialized work. The CI profession involves not only technical interest and expertise, but an interdisciplinary emphasis on connection beyond the boundaries of computer programming.

**Help desk guru**

The second individual factor reflects CI professionals’ love for introducing and helping others with technologies. CI professionals cast them both in the inward-facing role of gadget geek and also the outward-facing role of bringing technical knowledge to users in a wide range of disciplines and backgrounds. One administrator from Colorado described entering the CI profession because, ‘I mean, I just enjoyed…the aspect of working with people. I came up more, you know, on help desks and doing consulting and helping people use computers’ (P014). Thus, the activity of helping itself involves boundary spanning, as CI professionals do not emphasize the dominance of specialized knowledge as bringing meaning to their profession, but instead emphasize the translation of that knowledge for others. Related to the connecting nature of a CI gadget geek, help desk gurus described meaning arising from the CI profession when connecting users and/or developers with new tools or ways of doing their work. This quality rests on the CI community’s constant raising of questions and concerns with no simple, existing technical solutions.

Acting as a help desk guru speaks to CI professionals’ natural tendency to solve problems with technology, not only to develop technology but also to develop as people. Our participants described enjoying the mental stimulation of the profession. For them, CI is a puzzle they enjoy attempting to solve. When asked whether the ease of using CI or the technical ability to enable advanced work was more important, an administrator from Illinois said:

> I think it’s really the latter [the ability to enable work]…People who go the extra mile, who embrace the challenge of something more complex, in the end, end up being rewarded by it, by getting better results. Certainly…in our field. So, I don’t think ease of use is necessarily the first thing that is important—from my perspective anyway. (P013)
This professional described CI’s complexity as a positive, rather than a negative, for professionals within the field. The meaning of the profession arises not only from a geeky passion for the technologies, but also the complex puzzles that arise when different fields must use the networked technologies to solve widely diverging problems.

The problem-solution nature of a help desk guru also causes technological innovations that further layer meaning onto CI as a profession. Because of CI’s sprawling and still-developing nature, the problem-solving skillset of help desk guru professionals leads to them being ready for a challenge. They describe excitement in playing a role in constructing such a cutting-edge and large-scale innovation, an infrastructure that will shape scientific discoveries in years to come. An administrator, technologist, and liaison/facilitator from Idaho said:

I like being on the leading edge a little bit just because it’s more exciting and more, you know—you’re doing new things. You’re not… following a cookbook approach or something like that. You get to play with it. (P053)

This professional describes that the helpful quality of CI professionals causes interdisciplinary people to work together and complex puzzles to arise. In addition, CI offers status boosting through innovation and ambition. As explored by Freidson in other contexts (Freidson 2001), CI encourages individuals with the problem-solver quality to display an ambitious nature with both their scientific and professional career. The CI professional hopes to go beyond what has been done by others, reaching the very edges of what has been considered possible with research before. The character patterns that CI professionals use in their sensemaking narratives begin making the profession of CI meaningful through bracketing gaps and needs in existing fields and labelling ways their characters fit within those gaps and needs. However, the enactment of CI as a meaningful profession can only be realized further in the situational level of the professionals’ career journey narratives, or setting patterns, as described below.

**Pattern 2. Situational factors: ‘I met CI by accident!’**

The character roles or individual factors described by participants act as tickets to enter the fluid and convergent world of CI. If individuals relate to the roles above, then they may be appropriate for the CI profession. However, they must still immerse themselves within the boundary-spanning world of CI before being a full-fledged CI professional, with the CI profession enacted through their sensemaking stories. Our participants described a setting for CI infused with various pressures and influences that presented reasonable and engaging motivations for embracing the technologies and profession. Situational factors that characterize the place of CI among disciplines include the needs of professionals’ scientific research and the dictates of student experiences early in their careers. In general, the situational factors can be described as ‘I met CI by accident!’

Professionals joined the CI profession due to the right timing. Priorities and circumstances of the period when an individual came of age professionally influenced decisions to join the CI profession. For instance, a scientist-developer and liaison/facilitator from Utah described becoming interested in computers and programming because ‘it was kind of hip at that time’ (P012). CI developed at a time when computers represented an exciting new future of connection and knowledge, enabling collaboration and research previously thought impossible. A technologist, administrator, and scientist-developer from Arizona described, ‘It was a perfect timing to be at the right place at the right time’ when the domain science field this person was in started drifting towards computational methods (P021). Certain conditions fostered such an environment of interest and excitement, including emphasis on being cutting-edge and pioneering an innovation that will define the future.

Further, timing was important on an individual level for the professionals in their decision to adopt CI as their career path. Most of the professionals described first adopting CI during graduate school, while others adopted earlier in their educational careers. Individuals seem to enter the CI profession during a time when they are (1) often exposed to and intensely interested in pursuing new ideas, (2) acclimated to experimenting with work processes, and (3) searching for what to do with the rest of their professional lives. Most CI professionals begin their CI journey similarly to what an administrator and liaison/facilitator in Oklahoma described: ‘When I was a wee lad back in grad school’ (P037). Rarely do individuals enter the CI profession later in their careers, perhaps due to the field’s specialized nature or the field’s specific qualities, such as a need to be open to constant adaptation of workflows and a wide breadth of new ideas to learn and put into practice.

Thus, timing plays a big role in professionals’ motivations to join the CI community, both perceptions of the larger environment of the time that encourages cutting-edge technological exploration as well as personal timing in one’s career. While in many fields timing plays a role in an individual joining a professional field, CI’s timing is unique in that there are no standardize paths to grip a professional early in their career, such as established college majors, degree programs, or even courses. Instead,
the timing must arise within a situational window of interdisciplinary convergence. We elaborate below on how CI professionals enact CI as a profession through the situational level of their career stories, by which we mean the setting or figurative ‘place’ of CI among other disciplines in narratives.

**Student experience**

The first situational factor describes how many CI professionals came to the field by accident when they were in an environment of mentorship, interdisciplinary learning, and practical experimentation. Many participants noted that they became involved with CI while a student, as CI became necessary when needed for professional advancement, recognized as an avenue to make unique contributions to projects, and/or a mentor encouraged or required CI’s use for projects. A technologist, co-producing user, and peer user from Nebraska said:

...[M]y undergraduate advisor [in physics] came in one day and said, ‘By the way, you’ll need to learn to program. Learn Fortran.’ And that was the way that I was introduced to it [cyberinfrastructure]. And then as an undergraduate I helped to sort of build and administer just a small handful of PCs—I guess I will probably be the very first [CI]…they didn’t call it CI then, of course. (P023)

This professional mentions gaining entry to projects due to a mentor guiding them towards developing CI-related skills. The openness to mentorship within the context of student experience offers opportunity for CI to begin being characterized as a meaningful profession, one a student could choose as a career path.

Importantly, the accidental introduction to CI arose within an interdisciplinary environment. For instance, in the above professionals’ experience, CI-related skills opened a place where the field of physics collided with computer science. Although, ‘they didn’t call it CI then’, the convergence of disciplines created a space where the activities, concepts, and profession of CI was needed to bridge the gap. In other words, a situational window opportunity for CI emerged. A newness of perspective and sense of continued learning fostered by time as a student encouraged newcomers to join the CI profession. An administrator from Colorado described:

Even as an undergraduate in college I was the first computer consultant they ever hired…for the university. I went to help students with their—you know, use the campus computing resources. And so I was exposed pretty early. And then in grad school, just because I was good with computers got sucked into doing…[CI] that kind of work. So you know, kind of the role of computing and academia for engineering, for science—kind of just been there from my early college days. (P014)

Again, this professional describes ‘the role of computing and academia for engineering’, the converging of different disciplines that created a need for CI-type work. Within narratives about CI, the technologies involve continual learning about different disciplines, a process sparked during student experience within an academic environment.

Further, the above professional mentions another key element of the setting of CI: the interdisciplinary experimentation encouraged in academic research contexts. Not only does student experience with CI provide mentor-guided direction and opportunities for learning, but also experimentation towards practical, meaningful outcomes. Early student experience provides the essential setting details of (1) mentoring academic environment and (2) interdisciplinary convergence that creates gaps in understanding, the combination of which creates a situation that can only be navigated through CI. Because experience as a student is a time of exploration, seeking new ideas, and pressures to leverage freshness of perspective rather than established practices, such a phase is essential for inviting new people into the CI profession.

**Work’s necessity**

The second situational factor demonstrates that CI professionals came to CI when they realized that their early work in science needed CI. In other words, their professional work, rather than just early student work, opened situational windows for CI. Many participants described entering the CI profession because CI technologies were uniquely able to make previously unexplored scientific work possible. An administrator from Illinois described interest in using CI because ‘it’s a tool to get things done’ (P013). Similarly, a scientist-developer and co-producing user from California described, ‘I slipped into computing by mistake because it was necessary to get my science done and as I’ve found out that I’m good at this and this actually works well’ (P016). Along the same lines, a technologist, co-producing user, and peer user from Nebraska said, ‘And it was, you know, again, really just that it was necessary to do the science’ (P023). Even CI professionals who do not use the tools for their own research mention enabling others to carry out their work as a driving force giving meaning to their profession. In other words, the roles of ‘gadget geek’ and ‘help desk guru’ only
become meaningful when situated within a setting appropriate for CI. The pursuit of technologies that would enable scientific work in the ways that interested the participants often influenced the boundaries drawn between disciplines and the defining of CI as a distinct, necessary profession. When asked what first made CI attractive to them, an administrator, scientist-developer, and co-producing user from California said:

Actually, it wasn’t attractive, to be honest. In fact, a lot of people at the time said you must be crazy. Nobody who ever does this comes back and does science again because they said—it’s a little bit off a perception in my community that building the detector is really where the tools are that matter and software and computing is an afterthought. That’s changed over the years a little bit, but when I started, nobody valued computing as a service task. People looked at it in my discipline as—Okay, the people who do this, they’re just weird. (P016)

This professional describes that pursuing CI as a profession is not only logical, showcasing that the professionalization of CI does not rely solely on established signals of legitimacy and is instead an ongoing process of layering meaning onto the field and its work practices. Further, in this professional’s experience, the specific work of enabling advanced computational-driven scientific work as carried out by CI professionals did not fit neatly into another field. Thus, the CI profession began to form as an area where specialized workers could share ideas and standards, as more individuals adopted the area for their careers. As with sensemaking in any context, the professionalization of CI happened collectively, as professionals within the situational window opened by disciplinary convergence began sorting out who they were and what their job was.

Stories about CI open a window for sensemaking that both interacts with and differs from the boundaries of other established professional fields. Another analogy could compare CI to a religious denomination in which members believe themselves to be related to the larger religion, yet distinct in their own particular calling, Although CI involves computational methods and developing technologies, CI professionals would not consider themselves only computer scientists, or only engineers, etc. Instead, CI professionals feel distinct in their sense of purpose and identity (Berente et al. 2017). CI professionals believe in a unique mix of computational skills, research standards and focus, and a mission to provide support that enables others to access the system and do more than could be accomplished with research before. While the character roles of gadget geek and help desk guru lead individuals towards a natural interest in CI, the enactment phase of the sensemaking professionalization process for the community occurs in the situational, or setting, layer of their storytelling, as CI professionals describe an environment constrained by academic standards and practices in which disciplines converge in surprising and complex ways. When someone who labels themselves as a gadget geek and/or help desk guru and describes the setting of their profession in this way, the situational window for adopting CI as a profession opens.

Pattern 3. Inspirational factors: ‘CI is my calling!’

If individuals consider themselves the character roles described above and find themselves within the setting of CI, the final step to CI professionalism involves the inspiration to act, or perform the patterned work tasks within that setting. In other words, they must perform the selection and retention phases of the ongoing sensemaking process, focussing on important qualities of their situation and then retaining those qualities when deciding upon present and future actions. Our participants described CI technologies as having qualities that inspired them to join the CI profession. Such perceptions of the technologies included capabilities deemed necessary for scientific work not otherwise possible, broader accessibility to computational methods through increased connection that makes the process faster and cheaper, and the exciting nature of the technologies which step beyond what had been used for science before. The inspiration factors involve feeling that ‘CI is my calling!’ through (1) awe of systemic computing innovations and (2) appreciation for boundary-spanning interdisciplinary work.

The inspirational factors refer to CI professionals’ general sense of faith in CI’s vision to advance science. Participants described CI technologies as ambitious and visionary, reaching beyond other visions for computational tools and how they could be used. The meaning that CI professionals layered onto their work tasks touched on the point of big data in general, addressing what Hoare and Milner termed as ‘grand challenges’ of research, problems so huge and unwieldy that they cannot be solved by human perception alone (Hoare and Milner 2005). A liaison/facilitator, technologist, and user from North Carolina described:

When I saw that computers were actually very useful to scientists, and that they were being used all the time, that became very exciting to me. Also, learning about just the massive scale of computing that happens was really exciting to me as well. Just the thought
that people were still always trying to build bigger and faster computers. Honestly, that I could play a role in that was a big part of it, as well. (P112)

This professional mentions the excitement of being useful, the massive scale of technologies, and the ambitious trajectory of CI as meaningful reasons to work on CI. Through a retrospective story, this professional selected the routine work tasks of developing technologies, helping users, etc., with a larger sense of meaning for the CI field. Their sense of meaning provided the motivation to navigate the CI profession.

Overall, the vision of the ambitious reach and capabilities of CI brought meaning and purpose to the actions of CI professionals. A driving force of the CI profession included what is almost a calling: a shared passion for going above and beyond established technological capabilities. For instance, an administrator, scientist-developer, and co-producing user from California noted that despite some federal funding, ‘the majority of people in some of these [CI-supported] projects are not on [payroll]. They collaborate because they have the same vision’ (P016). Despite a dispersed nature and lack of centralized formal standards, individuals within the CI profession do retain shared values and hopes for the technologies they construct, maintain, and rely upon. This shared sense of meaning inspires the repeated actions and work tasks that then can become recognizable as a profession that may overlap with other disciplines but is unique in its purpose.

**Awed by systemic computing innovations**

The first inspirational factor shows how CI professionals select as meaningful to their profession how CI contributes to generating knowledge through developing and supporting systemic computing innovations. In addition to technological capabilities, CI promises increased public and researcher access to computational methods, making the big data computational research process faster, more wide-ranging, and cheaper. For instance, an administrator, technologist, and scientist-developer from California said CI technologies make possible:

> Reducing time to solution by not having to go through the development cycle. Reducing the budget, the finance, by not having to support a large development and support team for some of the infrastructure. So somebody else is already doing it, let’s just use it. (P022)

The experience of this professional showcases that although the activities of CI may be the same as other fields, such as computer science, engineering, etc., the priorities are different. Rather than just trying to make technologies that work and meet users’ needs, CI professionals are inspired to make the capabilities cheaper and more streamlined. For instance, in this case, the professional would rather mix-and-match work from other areas rather than trying to reinvent a separate tool. In other words, the focus is not on technology development for its own sake, but on computational innovations that adhere to the values of the CI community and are compatible with the overall CI technological system.

The infrastructural values described by the participants marked another distinction between the CI field and other fields, even though those same values may push CI to overlap with many disciplines through the mix-and-match process described above. One co-producing user and scientist-developer from Colorado described the development of the term for CI as ‘a growth on infrastructure and…a growth on what we were calling different computer things as “cyber”’ (P071). Noting the distinction between other fields and CI, a technologist from Massachusetts said:

> It’s building infrastructure… that’s a contribution to knowledge and it’s also reusable cyberinfrastructure project. It’s simply not computer science, at least as we define it. It begins to give you an understanding of the real roadblocks… I always say that… research could not be conducted without it [cyberinfrastructure]. Which is to say, that people tend to downgrade the effects that infrastructure and the importance of infrastructure while actually it’s running everything. (P127).

This professional captures the excitement of working on CI, in which projects are not isolated by are instead small parts of a much larger, more revolutionary system. In theory, despite at times failing in practice, infrastructures involve widespread accessibility; all the separate pieces of the technological system must be compatible with the rest of the system as well as co-existing systems. Infrastructures are disruptive and revolutionary, changing everyday life through their interoperability and interconnection, while eventually being considered routine. CI professionals are inspired to carry out the work tasks of their profession by an awe for such systemic computing innovations, the ability to mix-and-match technologies so they can accomplish more together.

**Appreciative of interdisciplinary work**

The second inspirational factor selected by CI professionals as meaningful to their profession refers to CI professionals’ appreciation of boundary-spanning...
interdisciplinary work. As already described, the setting of CI is one of disciplinary convergence. In fact, the convergence of disciplines opens a window for CI to form as a distinct profession in the first place. The overlapping of other professional communities for the participants led to certain forces that motivated individuals to adopt CI. These forces also included a need to make sense of the specific overlapping of communities through comparisons to existing fields that defined what makes the CI profession distinct. For instance, participants brought up the need for an infrastructure that enables interdisciplinary collaborations, which can prevent repeated work efforts, promote shared findings, and lead to new directions for research. An administrator from Illinois described:

Being able to work with somebody who’s... cross-disciplinary was pretty amazing. And again, it has also to do with my interest in collaboration and working with people of different backgrounds. I think that can be a huge driver for somebody to really engage in that.... And that is for me, interesting.... (P013)

So, in this professional's experience, interdisciplinary work is not only a need driven by the gaps between various disciplines but is also an inspirational value. Unlike the professionals already discussed when describing the external 'work's necessity' setting factors, the interdisciplinary drive here is internal: a genuine 'interest in collaboration and working with people of different backgrounds.' CI professionals feel inspired to act within the environment of CI because both their character roles and the specific situation of CI encourages appreciation of interdisciplinary work.

Participants also described the professional advancement opportunities that the CI profession and technologies offer. A co-producing user, liaison/facilitator, and scientist-developer from California recalled the pressure to publish early in their career, ‘Because at the end of the day, I just need to publish as many papers I can’ (P114). Many disciplines in academia echo such priorities. However, CI offers a new view on publishing standards and pressures, emphasizing and enabling publishing entire datasets as well as articles. A technologist from California described that philosophy about open science and publishing data:

...made people be like, ‘Huh. Maybe it’s not totally just about like “Do whatever it takes for me to publish,” because if I’m doing something that’s sort of scientifically, ethically incorrect or wrong, then that’s definitely not gonna further my career.’ So then this has slowly developed into an ideology where you’re open with your entire research process. Everything is transparent. Still, data sharing isn’t perfect, but it’s growing to be like a thing, because now you can actually sort of publish a dataset versus before there were no sort of avenue to do that. (P103)

Although advancement and recognition opportunities such as publishing may be an inspiration for work tasks in a variety of other fields, the meaning of CI work differs. Rather than making an impact in a specialized, siloed area, CI professionals appreciate interdisciplinary priorities that emphasize transparency and sharing, as mentioned by the professional above. Again, the focus with CI as a profession is not dominating a specialized area of knowledge, but developing fluid and boundary-spanning knowledge that can be used to overlap a wide variety of disciplines.

As seen in all these interlocking narrative patterns, CI professionals engage in sensemaking to conceptualize the boundary-spanning profession of CI. Professionals do not describe CI as having a set of technical categories separate from other fields and do not attempt to establish exclusive dominance over a specialized area. Rather, CI as a profession is enacted through ongoing sensemaking narratives which allow for the field to span many disciplines while developing its own unique sense of meaning. The bracketed and labelled character roles of gadget geek and help desk guru encompass the qualities that make an individual compatible to the field of CI. The situational level of factors offers key setting details that enact CI as a distinct, yet fluid, work area. Qualities such as disciplinary convergence during an individual’s student experience and professional work open a window of opportunity for professionals to engage with CI, if they fit within one or both identified character roles. Finally, a level of inspirational factors inspires CI professionals to engage with CI through work actions that further layer meaning through selection and retention onto CI as a boundary-spanning profession. Through all the patterns we identified, we find that CI defies pure technical rationality as a profession; logically, work tasks and individual characteristics correspond to many other fields. However, the meaning layered onto those tasks and connecting them within narratives showcases a distinct profession, albeit a fluid one. We discuss the implications of this important finding below.

**DISCUSSION**

Our study emphasizes that professions are unfinished, constantly shaped and reshaped through sensemaking processes and patterns, including personal retrospective career stories. In other words, professionalization
is a sensemaking process. Professions may gain their credibility from cultural meaning and their importance through institutional support, and they may begin forming through logical and categorical separation from other fields. However, professions only fully emerge when individuals incorporate them into their personal stories. Thus, expanding on the work of Weick, Browning, and others who have studied narrative sensemaking in organizational contexts, individuals rationalize their professions through narratives as well as logical catalogs and categories (Browning 1992; Weick 1995; Brown, Stacey and Nandhakumar 2008). While CI is characterized by an overarching relationship with established fields, CI professionals use narratives to span the boundaries of converging disciplines, dramatizing and personalizing CI’s qualities and aims, especially when describing the situations that led to them joining the field.

According to the narrative patterns we discovered, CI professionals qualify CI as inherently computing technologies for big data and science. For instance, with CI, despite sharing emphasis on programming and computational advancement with computer science and technical problem-solving with engineering, several qualities highlight CI’s distinctions: a focus on infrastructural logic such as remaining hidden rather than widely lauded; a perspective of strangeness within other fields; and a value on open-science publishing and data sharing. We find that because of the nature of CI, embedded within other fields, the boundary-spanning profession exists in part through divergence from and convergence with established professional standards of the established professions that overarch the community. Given our findings, future scholars of professions could further examine uniquely manifested patterns in the converging of bodies of knowledge, rather than only dominance over a specialized domain, when attempting to understand boundary-spanning professions.

Guided by our RQ, we identified several narrative patterns that CI professionals used to make sense of their career in the boundary-spanning CI profession. The patterns correspond to the basic elements of stories and showcase evidence of storytelling structure as identified by scholars such as Jones et al., including characters, setting, and action or plot (Jones, Shanahan and McBeth 2014). First, individual factors included the character roles of gadget geek and help desk guru; second, situational factors included setting qualities of the figurative place of CI among fields, including timing during student experience and work necessity; and finally inspirational factors included motivations for an individual to act within the profession. Including individual traits of CI professionals, situational introductions to CI, and inspirational convictions about CI, the three patterns for why professionals entered the CI profession could be used as an interpretive framework to explain boundary-spanning professions embedded in other contexts, while providing insight into how ideologies, senses of meaning, and storytelling shape the emergence of new professions. Given that there are no academic degree programs in ‘cyberinfrastructure’ at university campuses, and no one grew up as a child knowing that CI can be a career path, the three levels of individual, situational, and inspirational are key to explaining what attracts newcomers to join the boundary-spanning CI profession.

The patterns we identified indicate that retrospective storytelling remains a central mechanism in the development of a profession. The patterns welcome to new professionals, differentiate CI from other fields, and make the profession sustainable for professionals seeking a long-term career. Professionals’ career narratives layered meaning onto CI, providing the boundary-spanning profession with a sense of direction and distinction. The narratives detailed the personal journey of a narrator through a setting infused with various pressures and hazards brought about by disciplinary convergence, actively discovering technical solutions to people’s problems. Further, our findings indicate that while some previous scholarly thought on established professions rested on the presence of formal procedures, stability, and shared standards to offer logical distinctions with other fields, the CI profession instead thrives on continuous uncertainty, personal passion projects, and ongoing questioning of what the community and technologies can do for scientific work within the purview other fields.

Further, our study emphasizes that scholars of sensemaking, especially in the context of professions, should pay close attention to the situational or setting level of narratives. In our study, the setting qualities such as interdisciplinary forces opened the window of opportunity for a distinct, meaningful profession to be enacted. As seen in sensemaking literature, enactment includes individuals speaking complex concepts into meaning and understanding them through the process of articulation. Without those setting qualities in the situational level of the stories, the character labels of gadget geek and/or help desk guru may have gravitated towards identifying with other related fields. For instance, a gadget geek might have felt at home within strictly computer science, or a help desk guru might have become only a librarian, rather than also identifying with CI as a profession. The inspirational level of motivations to act within the profession also would not have formed without the setting qualities establishing both constraints and needs for action, the context for selecting and retaining meaningful qualities of
the profession. Without that inspirational level, patterned work tasks such as computing innovations and interdisciplinary collaboration would not be layered with the meaning that separates them from work in other fields. CI becomes a profession through storytelling, which makes meaning through connecting character roles and work actions to a specific, fluid, environment.

Moreover, on a practical level, the findings highlight that potential CI professionals must have individual factors that are then embedded in situational factors for the professional to connect with the CI community. Inspirational factors can motivate CI professionals to stay in the community for longer. These factors are key to understanding workforce development and retention. The fluidity of the sensemaking process for the profession also offers hope to further diversity, equity, and inclusion initiatives within the community, which, like many STEM fields, has struggled in the past to recruit and retain workers of diverse and/or historically marginalized identities. Our findings also suggest that professional identity in a boundary-spanning field (as opposed to a self-contained, established field) may be defined by the three levels of individual, situational, and inspirational. Therefore, scale development efforts to operationalize and measure the individual, situational, and inspirational factors could be guided by our findings, both in the context of CI and potentially in other contexts. Future work may also focus not only on retrospective stories, but how our framework could be applied to stories used in daily professional life.

This study also begins to articulate the distinct qualities of infrastructure professions more broadly, a topic of particular concern in the world today, given the US political preoccupation with critical public infrastructures (Boak 2022). Infrastructure professions are boundary-spanning areas of knowledge responsible for upholding complex, embedded technological systems. Infrastructures can offer opportunities for new professions to emerge, and, because professionals are agents of professions, infrastructure professionals develop and maintain the entrenched systems that shape future life. For instance, surrounding the widespread adoption and entrenchment of electrical grids, the new professions of electricians and electrical engineers arose from the broader field of engineering (Cohn 2017). These professions are central to both how the technological systems develop and how they are maintained. As coined by Russell and Vinsel, infrastructure technological systems include ‘The Maintainers’, or individuals dedicated to supporting and developing the involved technologies (Russell and Vinsel 2018). As already mentioned, surrounding the new concept of CI, scholars such as Lee et al. have already noticed the ‘human infrastructure’ of professionals necessary to the widespread establishment of the field and maintenance of the technologies (Lee, Dourish and Mark 2006). Due to the embedded nature of infrastructure and its widespread ability to shape everyday life, the professionals that develop and maintain these systems have a central role in shaping the future. Thus, it is essential that we study these professionals as well as the technological systems they implement. Future scholars could examine the professionals of other infrastructure contexts, using our framework of sensemaking narrative patterns as a starting point for analysis.

Of course, our study is not without its limitations. First, more work is needed to understand if and how sensemaking occurs in the professionalization of other fields, as well as noting any distinctions and comparable qualities in the process among different professions. Second, our data represent a snapshot of the CI community during a certain time and context. However, the community has evolved, such as redefining and naming ‘CI’ to ‘RCD’ in certain instances, attempting to be more inclusive as a professional community, adapting to changing priorities with technologies, attempting to facilitate beyond only STEM-oriented research, etc. Further work is needed to understand the ongoing nature of the professionalizing sensemaking narrative elements we identified. More long-term, longitudinal work would also better capture nuances between the convergences of different disciplines, as our study was preoccupied especially with computer science, engineering, and hard sciences due to the context of our data, perhaps. Interactions of other fields may yield further nuances in sensemaking narrative patterns about CI as a profession. Finally, in this study, we did not compare the narratives of CI professionals with different identities. Future work could compare narratives based on gender, sexuality, age, race, ethnicity, or even work roles, such as technologists versus administrators, etc., to uncover further nuances in narrative patterns.

CONCLUSION

In this article, we outlined narrative patterns for how cyberinfrastructure (CI) professionals created the meaning of CI as a profession. Specifically, we identified the individual traits of CI professionals, situational introductions to CI, and inspirational convictions about CI that uniquely influence CI professionals in joining the profession and where they situate the meaning they find in their work. The elements we identified speak to why CI is considered a distinct profession, one embedded within other overarching fields such as computer science and engineering yet separate in its vision and ideologies. Our findings indicate that the situational level of narrative
patterns professionals use to describe their careers are particularly important to the development of a boundary-spanning profession. The situational level of qualities about the environment of a profession offers a window of opportunity for the profession to become distinct and meaningful. Our work has theoretical implications for understanding the role of sensemaking in twenty-first-century professionalization, the emergence of professions, and infrastructure professions specifically. On a practical level, our study also provides insight into how boundary-spanning fields such as CI can build the next generations of their workforce.

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REFERENCES


