



# Fostering a Thriving Virtual Organizational Culture: The Development of Metrics for Ten Soft Skills in the Case of XSEDE

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## Abstract

The purpose of this study is to propose a framework through which an organization could identify, describe, and measure ten factors categorized as soft skills shown to undergird the thriving culture of XSEDE, NSF's largest cyberinfrastructure project during 2011–2022. We conducted 54 interviews of XSEDE collaborators; these interviews proceeded in two phases, with the second functioning as member checks to ensure our findings accorded with respondents' experiences. Based on a grounded theory analysis of these 54 semi-structured interviews with a range of XSEDE stakeholders, we identified 10 social and cultural factors contributing to XSEDE's success: (1) communicating intentionally, (2) maintaining relationships, (3) helping colleagues and users, (4) trusting colleagues, (5) having thick skin, (6) assuming the best in others, (7) respecting colleagues, (8) remaining open-minded, (9) practicing transparency, and (10) showing appreciation. We believe these ten factors can be used to create a methodology for developing soft skills metrics for virtual organizations and cyberinfrastructure projects similar to XSEDE. This would allow stakeholders to proactively measure engagement in behaviors, practices, and mindsets conducive to generating a thriving culture for virtual collaborations.

**Keywords** XSEDE · Virtual organizations · Cyberinfrastructure projects · Thriving culture · Soft skills

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## Introduction

The Extreme Science and Engineering Discovery Environment (XSEDE) [1], an expansive and successful large-scale collaboration, drew together high performance computing systems, software systems, visualization tools, networks, storage, and people to support them. Over its eleven active years from 2011–2022, XSEDE provided advanced cyberinfrastructure (CI) resources—systems and services—to a broad range of constituents, facilitating research on topics ranging from computational chemistry to animal genetics.

XSEDE was a unique organization in the history of National Science Foundation (NSF) funding in that it was the largest CI project, virtual organization, and collaborative consortium funded by the NSF to empower the scientific community in utilizing research computing resources in service of data-driven breakthrough science. Institutions that contributed CI resources to XSEDE included the University of California at San Diego, Indiana University, University of Texas at Austin, University of Pittsburgh, University of Southern California, University of Tennessee at Knoxville, and Georgia Institute of Technology. The institutions that contributed human resources in order to operate, administer,

and facilitate the use of these resources were far greater in number than the seven named here. As is generally the case in large-scale federally funded CI projects, XSEDE's PI and co-PIs were named in the grant proposal, with XSEDE having been funded in 2011 and XSEDE 2.0 in 2016. Other collaborators were charged with lending their expertise to the project, having built multiple years of experience under project such as TeraGrid. Despite the roughly 300 XSEDE collaborators spread across the United States when fully virtual teams were hardly the norm, XSEDE can be considered, by several different metrics, a successful collaboration. This is not to imply that XSEDE's thriving culture did not occasionally break down; positive and negative experiences are not mutually exclusive here, or in other similar organizations. Indeed, XSEDE's size, duration, and the complexity of its work make it an apt case study in devising a framework for successful collaborations, particularly within virtual teams and organizations, a pertinent issue in the current workplace.

XSEDE's success as a collaborative virtual organization has been well established in several fields and via several different sets of metrics. Knepper and Börner offer an early bibliometric analysis, having studied the usage of XSEDE resources during the organization's first four years, and comparing the central processing unit (CPU) hours used (5,374,032,696) to the number of publications that cited the resource (2882). They concluded that, even in early days, projects spanned geographical areas, with users accessing resources independent of location to complete their work [2]. That is to say, the research persisted successfully based on the work of collaborators who were not collocated with the research teams, or, necessarily, with their own XSEDE teams. In this paper, our motivation is to identify qualitatively what made XSEDE successful to support such impressive scientific outcomes, and then to describe a methodology for developing the associated quantitative measures for metrics.

Regarding the National Science Foundation's sizable investment in XSEDE over the course of its active years, Stewart et al established the organization's success based on Return on Investment (ROI). Their analysis of a sizable data set shows, through a methodology borrowed from the field of accounting, that "the US government has received an ROI of at least 1.87 for its investment in XSEDE services. This represents a conservative estimate. An estimate based on what we consider to be the best available and most reasonable estimate of the value of XSEDE services results in an ROI of 3.24" [3]. This positive ROI indicates the organization's success from an accounting perspective. We explore the social and cultural factors (behaviors, practices, mindsets, etc.) within XSEDE that enabled it to achieve a compelling ROI.

XSEDE was an organization that sought continuous improvement; one method the organization employed to

determine where such improvement was needed was an annual staff climate study, carried out by XSEDE's evaluation team. The first study was conducted in 2013, and the last in 2022. These studies generally reported high levels of satisfaction in categories such as Leadership and Management, Equity, Inclusion, Support and Belonging, and Value and Satisfaction, among others. The reports, excepting the final report in 2022, also offered recommendations for organizational change in order to improve the climate. The final report found that, generally, "both staff and leadership report that interactions with other XSEDE staff members are extremely positive, and most feel valued and satisfied with their experience as an XSEDE staff member" [4]. Such observations point not only to the organization's success, but to the collaborative environment it fostered.

Currently, scholars in fields spanning computer science, organizational psychology, sociology, Science of Team Science, and many others, are asking the question, "what makes a collaboration successful?" and its integral follow-up, "and how can we tell?" Love et al. conducted a longitudinal study of a university's program to invest in and support interdisciplinary research teams using a mixed-methods approach. They found that measures indicative of positive outcomes for the teams included the proportion of women, strong social relationships, and turn-taking, and acknowledge the necessity of metrics that may take years to emerge [5]. With XSEDE's decade-plus bibliometric and outcome data available and already subject to analysis, and with the project having ended roughly one year after the inception of this study, the time was right to embark on a study in order to consider the complex web of ties within and between teams, technologies, and the outside research teams they supported.

Our work proceeds from a presumption of XSEDE's success as a CI organization in service of enabling scientific research. Thus, we explore what kept XSEDE's collaboration—and its many members—active and engaged over many years, what kept the organization coherent over shifts in leadership and personnel, and what kinds of behaviors that fostered a collaborative culture. To determine the strategies and tactics that made XSEDE successful as a collaborative virtual organization, this paper draws on data from interviews with XSEDE collaborators, foregrounding respondents' assessments of XSEDE's collaborative culture. Our findings build on those of the studies cited above in their emphasis on the importance of soft skills to a thriving organizational culture. Though first used in US Army training documents to differentiate them from "hard" technical skills and expertise, "soft skills" has come to denote a range of competencies including communication and interpersonal skills, leadership skills, work ethic, attitude, and problem solving skills [6]. The phrase, with its expansive definition, offers a shorthand for these many qualities and abilities,

which are integral to successful collaboration, within education, industry, and multiple academic fields.

This paper highlights the role of XSEDE's culture in enabling its successes, and seeks to determine the specific factors that made XSEDE's collaborations productive at the organizational level, within teams, and person to person. To do so, the paper begins by detailing our qualitative methodology, which employed the grounded theory approach in data collection and analysis. This analysis yielded first a list of ten soft skills that we then adapted into a composite scale, rendering XSEDE's level of organizational performance measurable. The process of turning soft skills into metrics is described in "[Turning Themes into Metrics](#)", and the composite scales are included in Appendix D. In doing so, we propose a set of soft skills by which XSEDE and other similar organizations might gauge the success of their collaborative efforts. We also hope to illuminate a method by which other organizations might determine their own sets of soft skills they would benefit from measuring, and a manner of measuring them.

## Related Work

In previous organizational studies of CI projects and science gateways (SG), multidisciplinary expertise has been deemed essential due to the fact that the grand challenges and issues investigated in these projects often transcend the boundaries of a single discipline [7]. However, the multidisciplinary nature of these projects can also pose challenges to the widespread adoption of SG/CI initiatives. Gesing et al. identified a specific challenge in achieving greater sustainability of SG through on-campus teams, highlighting the need to preserve the diversity of expertise within the multidisciplinary group to maximize project benefits [8]. According to Katz and Proctor, the SG/CI infrastructure itself must be designed to address and support collaborative, multidisciplinary teams [9]. This involves dealing with larger and more complex data while simultaneously promoting interoperability between systems and policies.

In another organizational study of CI/SG, Kee and Shrock asserted that the success of projects and tools can be measured by adoption rates, and this outcome can be enhanced by the social and organizational practices implemented by developer teams [10]. They outlined 12 specific practices to bolster team capabilities, including fostering multidisciplinary expertise, setting shared goals, using common language, having bridge liaisons, establishing productive routines, conducting face-to-face meetings, demonstrating altruistic leadership, defining clear goals, incorporating user feedback, securing sustainable funding, building organizational capacity, and ensuring personnel continuity. These practices, as identified by Kee and Shrock, are

organizationally focused, describing internal actions among project members. In the present paper, we aim to identify the factors that contribute to cultivating a thriving organizational culture in XSEDE and similar virtual organizations.

## Methods

Between December 2021 and August 2023, we conducted fifty-four (54) interviews over two rounds (28 in round 1, and 26 in round 2). This research was approved by the Cornell Institutional Review Board (protocol #1803007842), and research was carried out in the manner approved. Informed consent was obtained from respondents prior to interviews (Informed Consent Statement included in Appendix A). Given compliance with the IRB procedures, the analysis reported in this paper is suitable for public dissemination.

This qualitative study was exploratory, seeking out the details and practices integral to XSEDE's productive internal collaborations, and those between XSEDE and external researchers. Our strategy was to elicit reflections from our respondents on what they found to be supportive behaviors for effective collaboration. This paper seeks to isolate these behaviors and present them in a manner that might potentially be useful to other organizations similar to XSEDE in measuring the productivity of their collaborations (see "[Results](#)" and "[Turning Themes into Metrics](#)").

## Recruitment

Our recruitment strategy followed what is known as the purposive sampling approach [11]. Purposive sampling is a non-probability sampling technique where researchers deliberately select participants for their study based on specific characteristics or criteria. Unlike probability sampling methods, such as random sampling, where each member of the population has a known chance of being selected, purposive sampling relies on the researcher's judgment to choose participants who are relevant to the research question or objective. In our case, we were specifically looking for members of XSEDE who could tell us about XSEDE's culture; participants who did not have direct experience with XSEDE would not qualify. Purposive sampling is often used in qualitative research where the emphasis is on understanding the nuances of a particular phenomenon rather than generalizing findings to a larger population.

Through all phases of data collection, we focused on recruiting collaborators at all levels and from all facets of XSEDE. We identified XSEDE staff members, both fully and partially funded, who were directly related to XSEDE's various functions (allocations, training, consulting, etc.) to investigate from the "base of the pyramid" up. We also recruited among XSEDE project leaders and

leaders of the functional areas, and interviewed five members of this leadership team, in seeking a broad view of XSEDE's collaborative structures and practices. Further, at the end of each interview, we asked for recommendations and referrals, fostering snowball recruitment. To increase diversity and improve the representativeness of our sample, we used the maximum variation approach [11] and asked respondents to think of referrals demographically, professionally, and institutionally different from themselves.

## Round 1 Interviewing

In the first round, interview questions asked respondents to reflect on collaborations within their teams, between their teams and other teams, with external research teams (when applicable), and with XSEDE leadership. The questions also prompted respondents to explore aspects of their participation in XSEDE that they found personally and/or professionally fulfilling. Interviews were conducted over Zoom with interview questions viewable on screen. Though the interviews proceeded organically, the questions provided consistency while still allowing for follow-up questions that probed more deeply into respondents' thoughts and insights into the collaborative methods intrinsic to XSEDE. The team conducted 28 Round 1 interviews; questions are included in Appendix B.

## Round 1 Transcription and Analysis

Verbatim transcripts were produced using Otter.ai [12] transcription software. Research team members edited the transcripts for clarity and accuracy, and then the transcripts were systematically analyzed using Nvivo [13] software and the grounded theory approach [14] to illuminate emerging themes. In keeping with this approach, the team created a summary of the results organized around these themes (rather than around the interview questions) in order to create a coherent story based on the respondents' answers.

The prominent topics that emerged in the first round of interviews included XSEDE's accomplishments; the micro- and macro-level activities that created XSEDE's broader culture; the role of communication breakdowns within that culture, and the reasons they occurred; job satisfaction; behaviors that help collaborators thrive in virtual organizations like XSEDE; and recommendations for such organizations. Specifically, respondents were attentive to the factors that hindered their collaborations and that fostered their success, and to the practices that would ensure the success of XSEDE's successor, ACCESS.

## Round 2 Interviewing (Member Checking)

In preparation for the second round of interviews, the team funneled these topics into the following five themes:

1. Thriving culture
2. Workplace satisfaction
3. Broader culture
4. Collaboration breakdown
5. Recommendations for ACCESS

We then created questions around these themes, and used the most prominent answers to create answer matrices with which the respondents were asked if they (1) strongly disagree, (2) disagree, (3) [felt] neutral, (4) agree, and (5) strongly agree. Each question matrix was followed by an open-ended question, allowing respondents to impart additional thoughts sparked by the preceding statements. Round 2 interviews lasted 18–40 min.

This second round of interviews focused on member checking [15]. Member checking is a qualitative research technique for verifying, validating, and disseminating early findings within a particular group (here, XSEDE participants) to ensure interpretations and articulations of those findings ring true for them. Member checking also offers respondents a chance to share additional information, and to dig deeper into important insights. As in Round 1, these interviews were also guided by a series of questions, and were allowed to proceed organically, with interviewers asking follow-up questions when doing so would offer clarification or further insight. Round 2 interview questions are included in Appendix C. In order to ensure that our framework was as comprehensive as possible, we asked participants "What else can help collaborators thrive in a virtual organization?" Their additional responses were incorporated into our analysis.

## Round 2 Analysis

The second round of interviews proceeded in three waves. First, after five interviews, the team performed a quantitative analysis using the Statistical Package for the Social Sciences (SPSS) to determine the degree to which respondents agreed with our themes and results at that point [16]; then, we did the same after 15 interviews. Thus, we made slight adjustments to the language of some statements. We then proceeded with another 11 interviews, for a total of 26 member checking interviews. To ensure confidentiality, the transcripts included only the professional role, and we use transcript numbers here to introduce excerpts. Throughout the paper, we identify respondents by a subject identifier for "respondent" (R) followed by a number in the order of their member checking interview.

After transcribing the second round of interviews, the team paid special attention to (mis)alignments between the two rounds of interviewing, looking for opportunities to triangulate the findings to develop a full, complex understanding of XSEDE. Where there were misalignments, we took that as an opportunity to explain conditions that may have led to some differences. Alignments, conversely, were treated as confirmation of commonly shared opinions and understanding.

The double rounds of interviews and preliminary analysis provided a foundational understanding of the motivations, concerns, and triumphs of XSEDE as a whole, of its collaborators as individuals and as parts of the larger ecosystem. What emerged were articulations of what motivated XSEDE collaborators to take on this sometimes additional facet of their work, of the relationship between competition and collaboration among institutions, and of the various challenges faced by the virtual organization and those working within it.

Given that our approach to this exploratory study is qualitative in nature, we strive, in the sections to follow, for transferability rather than generalizability, and to demonstrate a method for creating metrics for soft skills that contributed to XSEDE's thriving culture, a topic relatively unexplored to date in the field of CI and Research Computing and Data (RCD). We also include an instrument of ten metrics to quantitatively measure and assess the soft skills derived from our analysis.

## Results

We developed a framework of 10 soft skills based on two steps: analyzing 28 first-round interviews to form the foundation of the framework, and then using the additional 26 interviews to validate and/or add to the framework. Below, we present an analysis of a qualitative study of the 26 responses to the member checking interviews. XSEDE's contributors numbered roughly 300 people, and our total sample of 54 represents roughly 18% of the population.

While our approach is qualitative and our sample size may seem small when compared with those of quantitative studies, Boddy (2016) suggests that for a qualitative study, a sample size of 12 participants is usually sufficient to help researchers reach theoretical saturation [17]. Furthermore, Marshall et al (2013) also determined that in grounded theory studies, analysis can yield the richest results and reach theoretical saturation with about 20 to 30 interviews [18]. Theoretical saturation is a concept in qualitative research, particularly in methodologies like grounded theory, where researchers aim to gather data until no new information or themes emerge from their analysis. Essentially, when researchers reach theoretical saturation, it means they have collected enough data to develop a comprehensive

understanding of the phenomenon they are studying. At the point of theoretical saturation, gathering more data is unlikely to provide novel insights or perspectives. It indicates that the researchers have reached a point where they feel confident that they have explored the breadth and depth of the topic sufficiently.

Theoretical saturation is often achieved through iterative data collection and analysis, such as in the method described above in "Methods". Researchers continually compare new data with existing findings, looking for patterns, themes, and connections until they observe no new insights emerging. This process helps ensure the rigor and comprehensiveness of qualitative research findings. Given that we have 54 interviews in our dataset, and that we followed the grounded theory approach and constantly checked for theoretical saturation, we believe that our sample size of 54 interviews has helped us reach theoretical saturation and that the dataset is sufficient for this exploratory study.

In qualitative research, the emphasis is not on statistical generalizability to a larger population as in quantitative research. Instead, qualitative researchers aim for depth, richness, and complexity in understanding a particular phenomenon or context. In our case, the phenomenon we are interested in exploring is virtual collaboration, and the context in which we seek to understand virtual collaboration is XSEDE, a large supercomputing consortium for big data and scientific research. In qualitative research, the goal is not generalizability; rather, the goal is "transferability" [19]. In qualitative research, transferability refers to the extent to which findings from one study can be applied or transferred to other contexts or settings. Unlike the concept of statistical generalizability in quantitative research, which focuses on the applicability of findings to a larger population, transferability in qualitative research acknowledges the unique, context-bound nature of qualitative findings. Overall, transferability in qualitative research involves providing detailed contextual information, conducting research and comprehensive analysis, and encouraging readers to assess critically the relevance and applicability of the findings to their own contexts. It recognizes the contextual nature of qualitative inquiry while seeking to generate insights that may have broader resonance across diverse settings.

This paper presents findings from an analysis of responses to the following questions, specifically:

- To what extent do you agree that these behaviors help collaborators thrive in a virtual organization like XSEDE?
- What else can help collaborators thrive in a virtual organization?

Systematic analysis of these responses led to three broad categories of social and cultural factors (behaviors, practices,

and mindsets) broadly described as management structure (e.g., face-to-face meetings to supplement virtual collaboration, strategic redundancy for covering busy/unavailable members), group dynamics (e.g., shared vision, organizational identification), and soft skills (e.g., communicating intentionally, maintaining relationships).

Given the richness of the data, this paper is attuned to the third of these soft skills. We focus on reporting the 10 main themes emerging from our qualitative analysis that suggest a framework of factors to identify, describe, and potentially measure these soft skills. This approach was inspired by one of the respondents who shared, “[It is] all about soft skills... The emphasis on those things is... why XSEDE succeeded...[G]iven that we’re computer and technology people, there’s usually not a big emphasis on soft skills...” (R6). Of course, for CI to be useful and effective, the people involved must possess the technical skills and abilities essential to make the hardware and software operate; in a large-scale collaboration like XSEDE, though, soft skills may well have been similarly essential to making that same hardware and software work.

As a preview, the following ten social and cultural factors make up the necessary behaviors, practices, and mindsets leading to our soft skills framework: (1) communicating intentionally, (2) maintaining relationships, (3) helping colleagues and users, (4) trusting colleagues, (5) having thick skin, (6) assuming the best in others, (7) respecting colleagues, (8) remaining open-minded, (9) practicing transparency, and (10) showing appreciation. Among them, (2) and (10) are new themes that emerged during the last phase of member checking interviews, and the other eight are based on modifications and updates of themes identified for validation during member checking interviews. We use the term “framework” to refer to a coherent list of inter-related soft skills. We address how one might use this framework to create soft skills metrics for another organization in “[Turning Themes into Metrics](#)”; before doing so, we elaborate on each skill, beginning with the need for good communication. Please note, also, that we intentionally use “respondents” to refer to the people who participated in our study, and “contributors” to refer to the RCD professionals who participated in XSEDE.

### Communicating Intentionally

According to our respondents, it was vital for XSEDE members to communicate intentionally. In fact, this was especially important given XSEDE’s status as a virtual organization, with in-person contact limited for some, and nonexistent for others. A respondent shared, “... [H]ow would you thrive in it?... [C]ommunicating that you are going to [fall] behind on things you can’t keep up with, there’s more work than there’s a possibility of doing it,

which, once you come to that realization, it’s a lot better... Especially if you don’t have in-person contacts” (R13). This respondent explained that because XSEDE was a complex collaboration, when one member fell behind on a deadline, it could impact others in the collaboration. While falling behind is an understandable and common challenge in a large-scale CI project like XSEDE, the important note from our respondent is that, when one is falling behind, one must communicate proactively and intentionally to other collaborators, rather than leaving them wondering why a deliverable is missing or delayed.

Moreover, another respondent emphasized the need to communicate clearly, especially when answering a question. As the respondent recounted, “So, if you’re responding to a question that somebody has, are you taking the time to make sure it’s a clear answer for them? Are you rushing through it and just getting it out of your desk, right?.. [P]eople appreciated the clarity of [taking the time to ensure it’s a clear answer], because then they knew what they were supposed to do” (R22). This respondent’s insight is that the outcome of a communication exchange is often the information one needs to take the next action. If the communication is not clear, especially if it is unclear for informing the next action, the collaboration can be negatively impacted.

Also, communication is a two-way process; both parties need to communicate responsively. A respondent told us, “So I think the collaborations which worked really well were where the reciprocation was high. So just because we are responsive, doesn’t mean things will get done, because the responsiveness also needs to be there from the other side” (R26). This respondent highlights the fact that when everyone involved in the communication exchange is responsive, that makes the communication successful. Collectively, these excerpts from our respondents established the integral nature of proactive, clear, and responsive communication to XSEDE’s success and thriving culture.

### Maintaining Relationships

Second, it became clear through our qualitative analysis that an orientation towards maintaining relationships was another factor that helped XSEDE thrive. A respondent noted that it’s important to attend to one’s relationships with colleagues “throughout the lifetime of a project, because the characters come and go. And you also need to renew those relationships, because there are very few individuals associated with XSEDE or ACCESS who are 100% funded on those. So people have other things in their worlds and in their lives... [M]any of the individuals involved in XSEDE and today in ACCESS are also involved in many other projects” (R18). This respondent describes a unique aspect of XSEDE; not all collaborators remained active in XSEDE throughout the lifetime of the virtual organization, and very few of them

worked full time for XSEDE. One might assume, given the part-time nature and potentially short-term time-frames of their collaborations, that XSEDE members may not have had many opportunities and/or much motivation to cultivate relationships with each other. However, this same unfavorable context required that XSEDE collaborators be actively relationship oriented in order to make the entire virtual organization thrive. At the same time, maintaining these relationships also offered some respondents opportunities to collaborate on other projects concurrently.

As many writers in both the scholarly and popular press have noted, post-work-from-home, building genuine connections can be more challenging in virtual environments. A respondent added, “[E]specially for a virtual organization, it’s being intentional about connections... We hardly get to see each other. So it’s easy just to say ‘Okay, all of this is in an email. And that’s about it.’ But I think making connections is more than just email or a zoom call. So being intentional about creating and maintaining those connections is really important in a virtual organization” (R7). This respondent echoed the previous quote that being intentional about connections and relationships is key to working in a virtual organization, because otherwise, the virtual modality does not foster similarly organic relationships as easily as traditional brick-and-mortar organizations.

### Helping Colleagues and Users

Third, it is critical to be helpful to colleagues and users. A respondent commented, “[P]rior to XSEDE, many of the centers were, and continue to be, in direct competition with one another. And yet, they’re supposed to work together on something... [H]ow you manage that? Partly [it] is just being helpful to people... because it broke down some of the barriers for staff between the organizations and institutions” (R22). This respondent explained that one of the main reasons for being helpful was to overcome the inherent context of tensions that the collaborating centers in XSEDE were also in competition with each other for federal funding (e.g., NSF) and reputation (e.g., which site has more/better supercomputing resources). However, by intentionally being helpful, respondents reduced the effects of the competition that may well have been occurring in the background; this, in turn, led collaborators to see XSEDE as an entity to which they belonged, keeping XSEDE salient in their minds during their interactions.

### Trusting Colleagues

Fourth, successful collaborations, especially in virtual organizations, require trust, and the willingness to trust one’s colleagues. A respondent stated, “[T]rust is a whole topic that I could talk an hour about within these sorts of

things. And I would say that early in XSEDE, as we think of XSEDE over its 11-year lifetime, there wasn’t a whole lot of trust. But that developed over time. And then people became very trusting of one another, as they spent time working together on things. Yeah, I thought that was really important. But the willingness for folks to do that... I thought it was critically important to even get there” (R22). This theme follows the previous one about how a willingness to be helpful was integral in overcoming the pre-XSEDE tension (or post-TeraGrid tension, TeraGrid being the predecessor of XSEDE) between collaboration and competition. As trust developed in XSEDE over time, members came to see that working together through XSEDE meant they could achieve bigger, better outcomes and create greater impacts than those of individual centers. We begin to see here how multiple factors begin to converge and interact.

### Having Thick Skin

Fifth, within an organization in which roles and teams often shifted and changed, several respondents alluded to the necessity of “thick skin,” or the ability to take in criticism without becoming emotionally burdened by it. One respondent noted, “I’ve got some pretty thick skin. And that was very helpful. Earlier in the project, I thought this was less of an issue [than] later in the project... [M]y empirical observations are that we mostly saw issues around this for the newer people to the project... They didn’t know that we could have frank conversations with people [and] not just get pissed at you... But it took a while for people that were new to the project to acclimate to that and understand-Oh, that’s what’s going on. It’s okay to say, ‘Hey, this is what I want to see in things!’ as long as... you’re providing constructive criticism, right?” (R22). Again, we are reminded here that new members joined XSEDE, and some old members left, creating the need for constant socialization and acclimation of new members. This respondent explained that the factor of having thick skin may be something that must be cultivated as part of organizational socialization. As new members joined XSEDE, this factor of having thick skin might not have been immediately apparent to them. It takes time for new members to observe and understand a long-standing dynamic in which collaborators could interact honestly, even when there were differences of opinion.

### Assuming the Best in Others

Sixth, it is vital in any collaborative environment to assume the best in other people. A respondent recounted, “We ran into this issue, as you might imagine...It became more evident later in the project...But don’t assume that somebody’s trying to do something bad...Assume that they’re trying to do something good. And let’s figure out where we’re

mismatched...And we sort of had to have a principle of assuming no ill intent...[Be] positive as opposed to reacting in a negative way” (P22). According to this respondent, this factor of assuming the best in other people is a mindset that XSEDE collaborators consciously practiced, as working in a virtual organization deprives us of nonverbal cues to help members more accurately interpret each other’s words and actions. Moreover, we may also surmise that assuming the best in people is a factor that works in tandem with having thick skin.

### Respecting Colleagues

Seventh, showing respect to one’s team members fosters an environment in which people feel their skills and contributions are valued. One respondent recommended “being respectful when you deliver that feedback” (P8). This respondent further recounted a particular type of incident: “I did witness certain situations, especially at the in-person meetings where maybe somebody said something, and it was unintentional. And that person didn’t know how it was going to be received, and it turned into a heated conversation or just...being receptive to ideas [and] having some resistance around that...” This respondent echoed the previous theme of having thick skin by characterizing it as ‘having some resistance around’ the feedback. Here we continue to see how themes interact with each other, particularly between being respectful and having thick skin here. Moreover, the respondent continued and suggested, “Having allies or people in the room who can help those conversations flow or happen if the people do happen to disagree... some sort of moderation, if needed. So unbiased individuals who can somehow step in if a conversation gets heated...So I think that reminder that the group is a team, and everyone’s welcome to contribute...But...ensuring that everyone’s respectful at the end of the day, whether you agree or disagree. I think that’s really important” (P8). This respondent made several important points. Being respectful is important when giving feedback, and connects back to the factor of “intentional communication.” Otherwise, useful feedback could be misinterpreted and the conversation could turn in a negative direction. Also, if an argument does emerge, it is helpful if both the feedback-recipient and the feedback-giver have thick skin. At the same time, a neutral party to help moderate the situation could help those with differing opinions see the other’s perspective. This theme naturally leads to the next one about staying open minded.

### Remaining Open-Minded

Eighth, in collaborative environments, it is critical to be open minded to new ideas and critiques. A respondent said, “When somebody gives you feedback, a lot of that is

subjective; what’s their observation, right? And that can sometimes break people the wrong way...I did feel that people were generally very open-minded and open to feedback... [O]ne of the things that I think helped XSEDE immensely is that much of the feedback was encapsulated in the way that we used our metrics and targets. So it became a much more objective measure...—[T]his is what the data says! Well, there’s no judgment here—So we tried to minimize that. I think that that was really helpful” (P22). This respondent explained that in order to help others be more receptive to feedback, that feedback could be couched in metrics and data-driven targets, in addition to being respectful, as suggested in the previous theme. That way, the feedback seems less subjective and is less likely to be misinterpreted in a personal way.

Another respondent added, “[B]eing open minded in terms of ways in such a wide variety of CI that we do, whether it’s from the user perspective, or from a systems perspective, just being open to say —Okay, just because we’ve done it this way all this time, [it] doesn’t mean we have to keep doing it this way. What new stuff’s out there? Can we do it better? More effectively? Can it make somebody else’s life a little easier?—So being open minded that way is a good thing” (P7). This second respondent adds a facet of open-mindedness that involves not being attached to old ways of doing things. New suggestions can come from people with different perspectives. In fact, this mindset of not being attached to previously employed methods allowed XSEDE to continue evolving and adapting to changing needs.

### Practicing Transparency

Ninth, another important soft skill involves practicing transparency. A respondent described this activity as, “having the people that are part of the leadership team be able to develop consensus on things so that they can move forward, and then sharing that transparently with everyone else” (R11). This respondent suggests that transparency has two dimensions: developing consensus within the leadership team, and then communicating that to the rest of the organization. This approach implies a democratic process to ensure transparency. What if the leadership decision is not shared by some members? Another respondent suggested, “If you were able to listen and give an honest answer as to why you can or can’t do something. People may not like it, but you’re being honest” (R20). This quote added the notion that being transparent also includes a means to engage those who differ with a listening ear and an honest answer about the constraints faced by the leadership. Collectively, respondents report that transparency is essential to a thriving organizational culture, and must be practiced with open communication, honesty, active listening, and consensus-building.



## Showing Appreciation

Finally, it is important to show appreciation for one's team and other collaborators. A respondent stated, "I very frequently heard project team members express appreciation to me for [who] I was. I'm a project manager. I'm doing a lot of grunt work, right? It's not necessarily the fun stuff... But people were always very appreciative... [and said], Oh, you know, this wouldn't have been anywhere near as great if you hadn't done this or this" (P17). What this respondent explained was that not every job and task is enjoyable and fun, and XSEDE members often had to do work that is perceived as less desirable or "grunt work." In this case, it was helpful for XSEDE members to show appreciation to each other, so members could lift each other's spirits during busy or difficult times.

## Turning Themes into Metrics

The ten interrelated soft skills described above emerged from the qualitative analysis of responses within our data-gathering interviews. They represent a framework of soft skills necessary for creating a thriving culture such as the one created within XSEDE, and potentially for other similar organizations. How, then, might we measure these soft skills quantitatively so as to create a set of metrics to help assess such an organization's collaborative culture?

Below we describe a methodology, common in social and organizational sciences, following the approach documented by DeVellis [20]. To begin, we break down one of the soft skills, explain how a researcher might approach measuring it, and offer a practical example of how this research, not as yet undertaken for XSEDE, can be performed. We do so with the goal of describing a methodology for measuring soft skills that can be employed by other organizations similar to XSEDE, and further, that can be undertaken by other organizations once they determine the qualities, traits, and social factors most usefully measured in their unique situations.

We begin by conceptually operationalizing the ten soft skills. Taking the first skill, "communicating intentionally," as an example, we operationalize the skill by identifying how intentional communication is demonstrated within a particular context (in this case, XSEDE). Based on the interviews summarized in the previous section, we noted that "communicating intentionally" means to communicate proactively, clearly, and responsively. We have then identified the three measurable dimensions of the first soft skill in our framework, based on the interviews.

Having broken the skill down into parts, we engage in composite scale development. In the social and organizational sciences, a "composite scale" is a quantitative measure

of a concept that includes its multiple dimensions. The purpose of a composite scale is to capture the full essence of a multidimensional concept through descriptive items in the form of statements, which allows respondents to indicate their degree of (dis)agreement with the items using a Likert scale. It is important to note that a Likert scale is a quantitative measure of agreement with the items, and it can be a 5-point, 7-point, 10-point scale, or any gradation; a composite scale, however, is a measure of a multi-dimensional concept, such as each of the soft skills in our findings.

Given this background, the composite scale of the soft skill "communicating intentionally" will consist of 3 items: (a) [proactive communication] "XSEDE members communicated proactively with each other," (b) [clear communication] "XSEDE members communicated clearly while working with each other," and (c) [responsive communication] "I could count on XSEDE members to be responsive in their communication with each other." The specific dimensions for each of the three items are listed in brackets for the purpose of clarity in this paper but would be omitted in the actual questionnaire given to respondents to rate with a 5-point Likert scale. In this case, 1/5 means "strongly disagree", 2/5 means "agree", 3/5 means "neutral", 4/5 means "agree", and 5/5 means "strongly agree."

After the response collection phase, we would calculate the individual composite scores for the soft skill of "communicating intentionally." As mentioned, we use a 5-point Likert scale to measure respondents' degrees of agreement with the 3 items. Let us consider the scenario that the first respondent would rate these 3 items with the scores of 5/5, 4/5, and 5/5, respectively (5/5 being the maximum score); in this case, the individual composite score for the first respondent would be 4.67/5, which is the average score of 5, 4, and 5. This means that the first respondent would have self-reported a high degree of agreement with descriptive items to measure "communicating intentionally," which reflects his/her confirmation that "communicating intentionally" is a skill that was commonly practiced within XSEDE. Generally, one can consider an individual composite score 2.49 or below to be "low," a score between 2.5 and 3.49 to be "neutral," and a score of 3.5 or higher to be "high." Other variations or gradations of how to label the range of this individual composite score can be developed based on the judgements of the researchers within their particular contexts.

Having established how to calculate a composite score, researchers can continue with calculating the organizational index score. To do so, members of the organization would fill out a short questionnaire with the three items of the composite scale to measure "communicating intentionally;" this provides individual composite scores. If we calculate the average of these, then we will have the organizational index score for "communicating intentionally" for XSEDE. Let us

consider a scenario in which the index score is 4.88/5. This would mean that as a group, XSEDE contributors reported a high degree of agreement that they observed and/or experienced XSEDE members engaging in the soft skill of “communicating intentionally.”

There are several positive aspects of this social and organizational approach to measuring concepts such as the ten soft skills discussed in this paper. The individual composite scores reflect a multi-dimensional concept that is often difficult to capture in a single item or statement. If we simply ask, “How much do you believe that XSEDE members communicate intentionally?”, respondents could easily interpret “communicating intentionally” as one of the three dimensions in our finding, thus leading to a less complete measurement of this soft skill. Moreover, if there are more than three dimensions to a soft skill, but the scale development effort only identifies three dimensions at this stage of the research, using a composite score (which is the average of three scores) is a better proxy of the “true” score of the concept, when and if the additional dimensions are identified in later research to yield a “true” score. Again, relying on an average score based on a composite scale is a better measure of a concept than relying on a single statement. Additionally, this approach will yield a quantitative score that is continuous in nature such as 4.67 and 4.88 in our examples (vs. a discrete number, such as 4 or 5 in the raw scores). This has statistical implications that we discuss below.

To ensure that the three items developed for the composite scale of “communicating intentionally” do indeed converge to measure a coherent concept of “communicating intentionally,” one can use the procedure of “Reliability Analysis” in SPSS [21]. More specifically, reliability analysis in the social and organizational sciences refers to the process of measuring the consistency of the items based on inter-item correlations. In other words, if the three items share a high level of inter-item correlations (on average) above 0.70, then the composite scale can be regarded as consistent enough to converge as a coherent measure of the concept of “communicating intentionally.”

This average inter-item correlational score is called Cronbach’s alpha, where the value of 1 means a perfect 100% correlation among all 3 items, and a value of 0 means no correlation at all. By running a reliability analysis in SPSS to generate the Cronbach’s alpha score, the analysis will also reveal which items deviate from the convergent concept so far that by dropping it, the overall alpha score would improve. This is especially helpful for composite scales with more items, such as 7 items, 10 items, or more. In other words, this analysis can help identify the items most necessary to measure a concept and help identify the peripheral items that can be dropped to simplify the composite scales.

While 0.70 is commonly considered the minimum score for a reliability analysis, some sources suggest that a 0.60

score may be acceptable as well, especially for a scale in progress. Also, a higher score may be desirable, but when a score is 0.90 or higher, it means the 3 items share too much similarity and redundancy, and thus do not have enough diversity among the items to capture a concept’s complexity. Deciding which score is acceptable may be a judgement call. Additional techniques, such as exploratory and confirmatory factor analyses, could be performed with the same composite scales described by Leech et al [21].

Taken together, metrics for the ten soft skills identified in this paper would be derived from composite scales developed to measure and capture their multidimensional complexity. If the Cronbach’s alpha score of each composite scale is 0.70 or higher, then the composite scale is deemed to have enough reliability to measure the concept. By administering a questionnaire that includes all 10 composite scales, 10 organizational index scores can be calculated by averaging the individual composite scores for all respondents in our scenario for all 10 composite scales. The 10 index scores can be used to assess how well the 10 soft skills were practiced in XSEDE. It is our hope that other organizations might benefit from devising their own lists of traits and social factors to measure, which might then be evaluated based on the methodology described herein.

## Discussion

In summary, the ten themes that comprise our framework of soft skills are (1) communicating intentionally, (2) maintaining relationships, (3) helping colleagues and users, (4) trusting colleagues, (5) having thick skin, (6) assuming the best in others, (7) respecting colleagues, (8) remaining open-minded, (9) practicing transparency, and (10) showing appreciation. Based on qualitative analysis of our data, these ten social and cultural factors (behaviors, practices, and mindsets) make up a framework of soft skills that can be used to quantitatively measure the factors that can generate a score or index to reflect areas in which XSEDE, or potentially a similar organization, was thriving, and those necessitating further attention, in order for an organizational culture to thrive. To serve as further examples of how soft-skills analysis might look within CI and RCD organizations, we have developed composite scales for all ten soft skills (please see Appendix D).

Intervention efforts can be implemented if a particular soft skill (e.g., showing appreciation or practicing transparency) receives a low index score. A study of by Kee et al (2021) [7] concluded that soft skills, such as communication skills, are teachable skills. With the methodology for quantifying soft skills metrics proposed in this study, XSEDE, ACCESS, or a similar organization could quantitatively track if and how these ten skills may improve after specific

training programs or incentives for organizational behaviors. Additional ideas can be found in resources by researchers in organizational studies, such as Scott and Lewis (2017) [22], and Miller and Poole (forthcoming) [23].

Moreover, as discussed above, soft skills often interact and complement each other in supporting a thriving culture. For example, we found that assuming the best in people, having thick skin, and being respectful are factors that may be important to work in combination during a difficult discussion, such as when someone gives another colleague feedback, and/or when there is a disagreement on a team. This insight prompts us to consider further analysis to see if other subsets of factors may cluster together for a particular type of social and cultural situation or challenge.

Additionally, if the proposed soft skills questionnaire collects demographic and/or professional information, intergroup comparisons (e.g., ethnic group 1 vs. ethnic group 2 vs. ethnic group 3; users vs. staff; etc.) of the soft skills (e.g., remaining open-minded) can be calculated using statistical procedures such as a *t-test* or an analysis of variance (ANOVA). If a certain outcome variable is also measured in the questionnaire, such as job satisfaction, productivity, etc. (also measured as a continuous variable), then a multiple regression can be performed to identify which combination of soft skills (e.g., communicating intentional + showing respect + having thick skin) may be most likely to yield a high level of satisfaction, productivity, etc., as an example. These inferential statistical tests are possible because the composite scale approach yields metric scores that are continuous in nature.

## Conclusion

In conclusion, this paper offers one analysis of interview responses in a study of the components of XSEDE's organizational culture. The grounded theory analysis of the 54 interviews has yielded rich data, opening many potential avenues of exploration for future work; based on the particular questions explored in this paper, we arrived at ten social and cultural factors that we believe are the soft skills that allowed XSEDE to thrive and be successful. As the field of CI continues to grow and professionalize, we must, of course, continue to pursue the technical and technological training necessary to foster its continued growth; we must also train CI professionals in the skills that will make them strong collaborators within this ecosystem. We hope that our method of developing first a framework based on qualitative analysis of an organization, and then composite scales as quantitative metrics for the items comprising that framework will allow organizations to track the soft skills and other social factors that allow them to thrive.

## Appendix A: Informed Consent

Informed Consent—CORNELL University Institutional Review Board Protocol 1803007842

You are invited to participate in a survey and interview conducted by principal investigators of the National Science Foundation-funded study EAGER: An Actor-Network Investigation of the XSEDE Project. We ask that you read this statement and ask any questions you may have before agreeing to take part in the survey or interview.

**PURPOSE** This survey and interview asks respondents to consider the factors that have motivated their participation in XSEDE. It will ask them to describe and discuss the specific methods XSEDE uses to balance cooperation, collaboration, and competition, and how XSEDE has encouraged interactions across divisions, creating a single, coherent organization. Information collected through the interview will be used to inform project insights regarding the design and governance for future organizations supporting cyberinfrastructure in the United States. Importantly, this research will provide insight about how best to organize large-scale collaborative projects and services. As a result, the study will increase the extent to which structure, leadership, and management of large cyberinfrastructure projects may be based on sound sociological science. These results, anonymized and aggregated, may be used in publications and presentations.

**Procedures for the Study** If you agree to participate, you will complete an online survey and an interview, for which there is no compensation. If you have received a link to this survey, you have consented to being interviewed. The survey should not take more than 3 min to complete. The interview will take 15–60 min, and will be recorded and transcribed for accuracy.

**Confidentiality** Every effort will be made to keep any personal information that you inadvertently disclose, as well as project data used to identify population members, confidential. All survey results will be reported in the aggregate and your identity will be held in confidence in reports in which the survey results may be published and/or in databases in which results are stored. Should the resulting data set be made public, it will be redacted of all identifying information. Archived data will be redacted of all identifying information and stored on secure Cornell University systems. However, we cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Organizations that may inspect and/or copy survey records for quality assurance and data analysis include groups such as the study investigator and his/her research associates, the Cornell University Institutional Review Board or its designees, and (as allowed by law) state or federal agencies, specifically the Institutional

Review Board for Human respondent Research (IRBHP) office.

**Contacts for Questions or Problems** Please direct questions about the survey and interview to Dr. Richard Knepper (rich.knepper@cornell.edu). For questions about your rights as a respondent or to discuss problems, complaints, or concerns about the assessment; to obtain information, or to offer input, please contact the Cornell IRBHP office at (607) 255-6812 or by email at irbhp@cornell.edu.

**Voluntary Nature of Study** Taking part in this survey and subsequent interview is voluntary. You may choose not to participate, to skip any questions you do not wish to answer, and/or to cease participation at any time. Doing so will not result in any penalty. Your decision whether or not to participate in this assessment will not affect your current or future relations with XSEDE, any institution involved in this study, or the National Science Foundation. This study was approved by the Cornell University Institutional Review Board on November 10, 2021. Please reference protocol #1803007842.

Do you agree to participate?

## Appendix B: Round 1 Interview Questions

1. For how long have you been a participant in XSEDE? In what capacity/capacities?
2. If you changed positions during your time with XSEDE, why and how did those changes happen?
3. Describe how you work with other XSEDE collaborators.
4. What kinds of results (positive and negative outcomes) have come out of that work?
5. In what kinds of interactions do you participate with your XSEDE team(s)? (How do you get stuff done?)
6. How do these activities and interactions give rise to XSEDE's broader culture?
7. Considering the tools you use for collaboration, why do you use those particular tools?
8. What's the intention between it/them? How do you use tools sequentially or concurrently to accomplish some goals?
9. How do you use different combinations and sequences of tools with different members of the same group?
10. How have interactions between collaborators (and not directly with users) worked in terms of serving end-user needs?
11. How do interactions between collaborators help meet XSEDE's goals? Specifically, how have these interactions helped offer access to different resources, create integrated services, and a coordinated environment?
12. Collaborators in XSEDE shared the same goal; how do you think this came to be?
13. Who is responsible for promoting a sense of coherence in XSEDE? How does the virtual organization execute projects that require multiple authorities to collaborate on specific items?
14. Have there been interactions during your participation with XSEDE that have been particularly satisfying?
15. Can you describe how those collaborations worked?
16. To what extent, in your estimation, is this type of collaboration consistent across varying roles in the organization?
17. Have you noticed any particular breakdowns in collaboration?
18. Can you describe any factors that seem to be behind these breakdowns?
19. In our preliminary analysis, we noted that participants told us about breakdowns due to timing issues, technological issues, communication from simply being human, and balancing between the virtual and the local.
20. How do you think it is best to address these breakdowns?
21. To what extent are you funded as a collaborator within XSEDE?
22. Have you received any benefits (tangible or intangible) via working with XSEDE? Can you describe them?
23. Describe how you balance your local and XSEDE commitments, and those of your multiple projects.
24. Did you work as part of TeraGrid? What are the contrasting experiences between TeraGrid and XSEDE? How did the staff climate improve from TeraGrid to XSEDE?
25. Many collaborators in XSEDE feel overcommitted at work. Overcommitment may increase in ACCESS. How can participants better manage overcommitment in ACCESS?
26. How does XSEDE membership help collaborators build soft skills/interpersonal skills that make them effective members of the collaborative virtual organization?
27. Did you go through a process to bring you "up to speed" with XSEDE? If yes, what did this process entail?
28. What behaviors does XSEDE membership require members to adapt in order to thrive in the collaborative virtual organization?
29. How does XSEDE work to cultivate these behaviors within and among members?
30. With which Work Breakdown Structure (WBS) areas are you associated?
31. How would you describe the style (or styles) of interaction within each area?
32. Have you observed any differences in interactions across the virtual organization?

33. Given anticipated changes in XSEDE, what do you see in your future?
34. Do you intend to stay engaged in the national community or will you turn your focus more toward your home institution?
35. How can ACCESS maintain what worked in XSEDE and implement new strategies to overcome the limitations of XSEDE?
36. What are the facets of the hierarchical structure of XSEDE that are not reflected in the flatter structure of ACCESS?
37. What is one thing you noticed that you think others in XSEDE might not already know?

### Appendix C: Round 2 Interview Questions

In this round, respondents were asked about the degree to which they agreed with each item on the following scale: 5 = Strongly Agree, 4 = Agree, 3 = Neither, 2 = Disagree, 1 = Strongly Disagree. They were then asked an open-ended follow-up question.

1. To what extent do you agree that the following activities/interactions helped create XSEDE's broader culture?
  - Creating an intentional structure for cooperation across partner sites
  - Developing a "all-for-one" mindset
  - Talking about strategies during meetings
  - Engaging in responsive communication
  - Participating in socialization activities to get to know others in XSEDE
  - Taking care of your staff and/or colleagues, so they can take care of users
  - How can XSEDE further cultivate a productive culture?
2. Based on your experience, to what extent do you agree that the following issues contributed to collaboration breakdowns in XSEDE?
  - Normal communication breakdown; simply being human
  - Timing issues, collaborators were late to deadlines, etc.
  - Technological issues, and/or when transitioning to new technologies
  - Balancing between local (i.e., home institution) and virtual (i.e., XSEDE)
  - How can collaboration breakdowns be reduced further?
3. To what extent did the following factors make working with XSEDE satisfying?
  - Focusing on mission and solving problems for users
  - Friendly users help us grow
  - People from work becoming friends, leading to a sense of belonging
  - Seeing a variety of research get done
  - Broadening access to advanced computing (i.e., MSIs)
  - Recognizing XSEDE's visibility in target communities
  - How can job satisfaction be increased even more in XSEDE/ACCESS?
4. To what extent do you agree that the following behaviors help collaborators thrive in a virtual organization like XSEDE?
  - Being a nice person; being helpful to colleagues and users
  - Communicating intentionally, clearly, effectively, and responsively
  - Being willing to trust that colleagues will come through and being trusted for the same
  - Always assuming the best in other people
  - Being open minded to new ideas and critiques
  - Having thick skin, putting ego aside, and reducing drama
  - Having the ability to change and/or pivot quickly based on users and situations
  - Being transparent
  - Being respectful
  - What else can help collaborators thrive in a virtual organization?
5. To what extent do you agree with the following recommendations to ACCESS?
  - Develop a more systematic onboarding process
  - Create a better balance between local and virtual commitments
  - Further cultivate trust in a virtual organization
  - What other recommendations would you offer to ACCESS?
6. What else would you like to tell us?

### Appendix D: A Composite Scale for Soft Skills

1. Communicating Intentionally
  - Proactive Communication: XSEDE members communicated proactively with each other.

- Clear Communication: In general, I would say that XSEDE members communicated clearly while working with each other.
  - Responsive Communication: I could count on XSEDE members to be responsive in their communication with each other.
2. Maintaining Relationships
- Frequent Check-ins: XSEDE members made a conscious effort to check in with each other on a regular basis for relationship building.
  - Relationship Opportunities: XSEDE provided many opportunities for cultivating relationships among members and collaborators.
  - External Collaborations: Many XSEDE members also collaborated on other projects (past and/or current) outside of the XSEDE project.
  - Non-work Interactions: During virtual and in-person opportunities, XSEDE members shared respectful non-work/personal conversations.
3. Helping Colleagues and Users
- Being Helpful—Collaborators: XSEDE members were often helpful to each other during collaborations.
  - Being Helpful—Users: XSEDE members were often helpful to XSEDE users during collaborations.
  - Remove Barriers: Intentionally being helpful to other XSEDE members helped remove barriers between organizations and institutions.
  - Uniting XSEDE: Making a conscious effort to be helpful to each other helped members create a sense of XSEDE as a united entity.
4. Trusting Colleagues
- Trusting: XSEDE members often showed a healthy level of trust to each other during collaborations.
  - Being Trusted: XSEDE members made an intentional effort to earn trust from each other during collaborations.
  - Growing Trust: The level of trust in XSEDE grew over time as members worked together on project tasks.
  - Bigger Together: XSEDE members had to learn to trust each other in order to achieve greater outcomes than they could have individually.
5. Having Thick Skin
- Take Things Well: XSEDE members were able to take constructive criticism from each other without taking things personally.
  - Respectful Feedback: XSEDE members often offered feedback in a respectful fashion.
  - Socialization: New members to XSEDE were actively socialized into a healthy culture of feedback and criticism.
  - Thick Skin: When an argument occurred, XSEDE members were able to have “thick skin” during the interaction.
6. Assuming the Best in Others
- Assume the Best: XSEDE members consciously assumed the best in other people during collaborations.
  - No Ill Principle: XSEDE successfully cultivated the principle of “assuming no ill intention” among its members.
  - Resolve Misunderstanding: Members were able to resolve misunderstandings appropriately when they arose.
7. Respecting Colleagues
- Feel Valued: XSEDE members felt that their skills and/or contributions were valued by others.
  - Respectful Interactions: Everyone interacted in a respectful manner with each other as XSEDE collaborators.
  - Neutral Mediator: When a disagreement emerged, neutral members were able to jump in to help mediate and moderate towards a resolution.
8. Remaining Open-Minded
- Open-Minded: XSEDE members were generally open-minded when working with each other.
  - Open to Feedback: XSEDE members took feedback from each other in a positive way most of the time.
  - Couched in Metrics: XSEDE members tended to comment on each other’s work based on objective metrics and data-driven targets.
  - New Ways: XSEDE members were open to doing things in a new way, as long as the new way improved things.

## 9. Practicing Transparency

- **Consensus:** XSEDE leadership was often able to reach consensus during decision making.
- **Sharing Transparently:** XSEDE leadership shared decisions in a transparent fashion with members and stakeholders.
- **Honest Leadership:** XSEDE leadership was able to explain honestly what they could or couldn't do when explaining decisions to members and stakeholders.
- **Listening:** XSEDE leadership listened to its members and stakeholders.

## 10. Showing Appreciation

- **Showing Appreciation:** XSEDE members often showed appreciation to each other.
- **Spirits Lifted:** XSEDE members felt that their spirits were lifted when others showed appreciation for their work.
- **Willing Grunt Work:** XSEDE members were willing to do the "grunt work" because they felt appreciated for their work.
- **Leadership Appreciation:** XSEDE leadership expressed appreciation for members' and collaborators' work.

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**Availability of Data and Materials** Not applicable.

**Code Availability** Not applicable.

## Declarations

**Conflict of interest** Dr. Winona Snapp-Childs and Dr. Richard Knepper were partially funded by the XSEDE project during part of the study (until XSEDE ended in August 2022).

**Ethical approval** This study was approved by the Cornell University Institutional Review Board (#1803007842).

**Consent to participate** All respondents consented to participate (please see informed consent statement in Appendix A).

**Consent for publication** Included in informed consent statement (in Appendix A).

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