

A Framework of "Soft-Skills" Metrics for Cyberinfrastructure Projects and Virtual Organizations: A Preliminary Analysis of the XSEDE's Thriving Culture

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Abstract

Purpose: The purpose of this study is to propose a framework of metrics to identify, describe, and potentially measure 10 factors categorized as "soft skills" behind the thriving culture of XSEDE, NSF's largest cyberinfrastructure project during 2011-2022. **Methods:** We conducted forty 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. **Results:** Based on a grounded theory analysis of 28 semi-structured interviews with a range of stakeholders of XSEDE, we identified that 10 social and cultural factors of (1) communicating intentionally, clearly, and responsively, (2) maintaining relationships, (3) helping colleagues and users, (4) trusting colleagues, (5) having thick skin, (6) assuming the best in other people, (7) showing respect, (8) remaining open minded to new ideas and critiques, (9) having the ability to change and/or pivot quickly based on users and situations, and (10) showing

appreciation. **Conclusion:** We believe these ten factors can be used as a checklist of metrics for virtual organizations and cyberinfrastructure projects similar to XSEDE, so respondents and stakeholders could pro-actively engage in behaviors, practices, and mindsets conducive to generating a thriving culture for virtual collaborations.

Keywords: XSEDE, Virtual Organizations, Cyberinfrastructure Projects, Thriving Culture

1 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 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 cyberinfrastructure project, virtual organization, and collaborative consortium funded by the NSF to power the scientific community to utilize research computing resources to do breakthrough science driven by big data. Institutions that contributed cyberinfrastructure resources to XSEDE included the University of California, San Diego, Indiana University, University of Texas, Austin, University of Pittsburgh, University of Southern California, University of Tennessee, 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. Despite the roughly 300 XSEDE collaborators spread across the United States beginning in 2011 when fully virtual teams were hardly the norm, XSEDE can be considered, by several different metrics, a successful collaboration. Indeed, XSEDE's size, duration, and the complexity of the work it undertook make it an apt case study in determining metrics 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 (2,882). 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 work 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 qualitatively identify what made XSEDE successful to support such impressive scientific outcomes.

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. This is important because ROI is difficult to quantify in an emerging enterprise, and wanted to identify 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, and 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. The paper highlights the role of this

culture in enabling those successes, and seeks to determine the specific factors that made XSEDE’s collaborations productive at the organizational level, within teams, and person to person. By exposing these actions, we propose a set of metrics by which other organizations, particularly large-scale cyberinfrastructure organizations, can measure in order to gauge the success of their collaborative efforts.

2 Methods

Between December 2021 and August 2023, we conducted forty interviews over two rounds, and surveyed an additional nineteen respondents (with no overlap between survey and interview respondents). 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).

2.1 Recruitment

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 leadership and key stakeholders 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. In order to increase diversity and improve the representativeness of our sample, we used the maximum variation approach [6] and asked respondents to think of referrals demographically, professionally, and institutionally different from themselves.

2.2 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), asked with XSEDE leadership. The questions also asked respondents to explore their motivation to participate in XSEDE. Interviews were conducted over Zoom with interview questions viewable on screen. While 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 collaborative methods intrinsic to XSEDE. Round 1 interview questions are included in Appendix B.

2.3 Round 1 Transcription and Analysis

Verbatim transcripts were produced using Otter.ai [cite] transcription software. Research team members edited the transcripts for clarity and accuracy, and then the transcripts were systematically analyzed using Nvivo [7] software and the grounded theory approach [8] 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 interview respondents' responses.

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.

2.4 Round 2 Interviewing (Member Checking)

In preparation for the second round of interviews, the team funnelled 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 generally lasted 18-40 minutes.

This second round of interviews focused on member checking [9]. Member checking is a qualitative research technique for verifying, validating, and disseminating early findings within a particular group – here, XSEDE respondents – to ensure interpretations and articulations of those findings ring true for them. Member checking also offers respondents an additional chance to share more deeply about their thoughts, 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 B.

2.5 Member Checking Survey

To improve coverage of our respondent pool, the research team created a survey based on the Member Checking interview using the same five question matrices and open-ended questions. Invitations were sent to XSEDE collaborators who had either not received or not responded to invitations to participate in the two rounds of interviews. The first invitation was sent on June 15, 2023; reminders went to non-respondents

on June 26, July 10, and August 3. The survey closed on August 31, 2023. Seventy-seven invitations were sent, and twenty-five surveys were started. Of these, eighteen respondents completed the survey.

2.6 Round 2 Analysis/Final Findings

The second round of interviews proceeded in two waves. First, after 5 interviews, the team performed a quantitative analysis using SPSS to determine the degree to which respondents agreed with our themes and results at that point; we did the same after 15 interviews. Thus, we made slight adjustments to the language of some statements. To ensure confidentiality, the transcripts included only the professional role, and transcript numbers within the article to introduce excerpts. Throughout the paper, we identify respondents by a subject identifier for ‘professional’ (P) followed by a number in the order of their member checking interview.

After transcribing the second round of interviews, the team calculated the average level of agreement for each item in each of the five matrices. We 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 often 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.

3 Results

Below, we present an analysis of a qualitative study of 28 respondents from the member checking interviews. XSEDE’s contributors number roughly 300 people, and this sample of 28 represents roughly 9.3% of the population. Please note 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. For the purposes of this paper in particular, we present the first of the three analyses, which addresses XSEDE’s successes in creating and promoting a cohesive and thriving culture.

Here, we present findings from an analysis of responses to the specific questions, “To what extent do you agree that these behaviors help collaborators thrive in a virtual organization like XSEDE?” and “What else can help collaborators thrive in a virtual organization?” Systematic analysis 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,

being relationship oriented). Given the richness of the data, this paper focuses on reporting the 10 main themes that suggest a framework of METRICS to identify, describe, and potentially measure this third category of factors categorized as “soft skills”. This focus 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...”. Of course, for cyberinfrastructure to be useful and effective, the people involved must possess the technical skills and abilities essential to make the hard- and software work; in a large-scale collaboration like XSEDE, though, soft skills may well be as essential to making that same hard- and software work.

As a preview, the following ten social and cultural factors make up the necessary behaviors, practices, and mindset leading to our framework of “soft skills” metrics: (1) communicating intentionally, clearly, and responsively, (2) being relationship-oriented, (3) being helpful to colleagues and users, (4) being willing to trust colleagues, (5) having thick skin, (6) always assuming the best in other people, (7) being respectful, (8) being open-minded to new ideas and critiques, (9) having the ability to change and/or pivot quickly based on users and situations, and (10) being appreciative. 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 will begin by elaborating on these themes next, beginning with the need for good communication.

3.1 Communicating

According to our respondents, it was vital for XSEDE members to communicate intentionally, clearly, and responsively. 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 you would 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” (P13). 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 cyberinfrastructure project like XSEDE; the important note from our collaborator is that, when one is falling behind, one must communicate proactively and intentionally to other collaborators, not 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” (P22). 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” (P26). 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 communication to XSEDE’s success and thriving culture.

3.2 Maintaining Relationships

Second, it became clear through our 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” (P18). 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 many opportunities and/or much motivation to cultivate relationships with each other. However, it is this unfavorable context and condition that XSEDE collaborators needed to be actively relationship oriented in order to make the entire virtual organization effective and 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. Another 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” (P7). This respondent echoed the previous quote that being intentional about connections and relationships with each other is key to working in a virtual organization, because otherwise, the virtual modality does not make relationships emerge and grow as easily as it would be in a traditional brick-and-mortar organizations.

3.3 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” (P22). This respondent explained that one of the main reasons for being helpful is to overcome the inherent context of tensions that the collaborating centers in XSEDE are also in competition with each other for federal funding (e.g., NSF) and reputation (e.g., which site has more supercomputing resources). However, by intentionally being helpful, respondents reduce the effects of the competition that may well be occurring in the background; this, in turn, lead collaborators to see XSEDE as an entity to which they belonged, keeping XSEDE salient in their minds during their interactions.

3.4 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” (P22). 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 that none of the individual centers could single-handedly accomplish. We begin to see here how multiple factors begin to converge and show how they may interact.

3.5 Having a Thick Skin

Fifth, within an organization in which roles and teams often shifted and changed, several respondents alluded to the necessity of a “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 in 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?” (P22). 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 is to 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.

3.6 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 must consciously practice, 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 also see that assuming the best in people is a factor that works in tandem with having thick skin.

3.7 Showing Respect

Seventh, showing respect to ones 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 [like having thick skin].” 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 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... but 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 being open minded.

3.8 Remaining Open-minded

Eighth, in a 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 how things have been done in the past allowed XSEDE to continue evolving and adapting to changing needs, as elaborated by the next theme.

3.9 Pivoting Quickly

Ninth, just as XSEDE collaborators needed to maintain an open mind, they occasionally needed the ability to change and/or pivot quickly based on users and situations. A respondent told us, “More often than most people know, because we intentionally constructed the project to be able to introduce new technologies, make changes, whatever they are, in a non-disruptive way. And so a lot of that change that was happening behind the scenes was behind the scenes. And the [user] community didn’t see it too much. But we just did it. And it was great” (P22). This respondent pointed out how change does not always have to be disruptive. In fact, the ability to pivot behind the scenes such that users on the receiving end do not even know a change has been made indicates XSEDE’s effectiveness.

3.10 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 say] – 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 must 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 can lift each other's spirits during busy or difficult times.

4 Discussion

In summary, the 10 themes that make up our framework of "soft skills" metrics are: (1) communicating intentionally, clearly, and responsively, (2) being relationship oriented, (3) being helpful to colleagues and users, (4) being willing to trust colleagues, (5) having thick skin, (6) always assuming the best in other people, (7) being respectful, (8) being open minded to new ideas and critiques, (9) having the ability to change and/or pivot quickly based on users and situations, and (10) being appreciative. We believe that these 10 social and cultural factors (behaviors, practices, mindsets) make up a framework of 'soft skills' metrics that could be further developed into a set of quantitative measures that can help virtual organizations and cyberinfrastructure projects (such as XSEDE, ACCESS) generate a score or index to reflect the soft skills that could promote a thriving culture in the organization.

Moreover, as discussed above, these factors 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, when there someone is giving another colleague feedback, and/or when there a disagreement on a team. This respondent finding prompts us to consider further analysis to see if a subset of factors may cluster together for a particular type of social and cultural situation or challenge.

5 Conclusion

In conclusion, this paper offers one analysis out of a mixed-methods study in which we conducted a mix of interviews and surveys. Based on a grounded theory analysis of member checking interviews, we arrived at 10 social and cultural factors that we believe are the "soft-skills" that allowed XSEDE to thrive and be successful. As the field of cyberinfrastructure 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 cyberinfrastructure professionals in the skills that will make them strong collaborators within this ecosystem. We imagine these 10 factors could be developed into a check list of metrics that similar virtual organizations and

cyberinfrastructure projects (such as XSEDE’s successor of ACCESS) could consider for guiding their virtual and multi-institutional collaborations in a complex context.

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6 Declarations

Some journals require declarations to be submitted in a standardised format. Please check the Instructions for Authors of the journal to which you are submitting to see if you need to complete this section. If yes, your manuscript must contain the following sections under the heading ‘Declarations’:

- Funding: This work is funded by the National Science Foundation award #2140226
- Competing interests: 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).
- Ethics 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).
- Availability of data and materials: Not applicable
- Code availability: Not applicable
- Authors’ contributions: Conceptualization: Kee, Jankowski, Knepper, Snapp-Childs; Data Curation: all authors; Formal Analysis: Kee, Brady; Funding acquisition: Snapp-Childs, Knepper, Kee; Investigation: all authors; Methodology: all authors; Project administration: Snapp-Childs; Resources: Snapp-Childs, Knepper, Kee; Supervision: Snapp-Childs, Knepper; Validation: all; Writing: all, review & editing: all

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 minutes to complete. The interview will take 15-60 minutes, 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: 1 = Strongly Agree, 2 = 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 are 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?

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