Collaboratories

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Abstract

Most interdisciplinary research projects involve geographically distributed participants. It is well known that such dispersion presents many challenges. The good news is that there are a wide variety of excellent technologies that can help bridge the distance among participants. However, there continue to be many challenges in how to make such projects successful. Fortunately, there is now a large body of research that suggests ways in which the challenges can be overcome. This chapter reviews the challenges and the interventions that can ameliorate the problems.

These days it has become commonplace in almost all areas of human endeavor to work with others who are not in the same location as you. Computing and communication technologies have matured to where it is relatively easy to carry out such activities, though as will be noted shortly, there are still many challenges. In the early 1990s these kinds of technologies began to get widespread attention as a form of infrastructure to support geographically distributed science and engineering. Wulf (1993) described an organization that exploits such infrastructure on behalf of scientific research as "collaboratories" and called them a "laboratory without walls." At that time a research group at the University of Michigan began to both build and study such collaboratories, an effort that has been maintained since. In a volume summarizing much of this work, as well as that of others, Olson et al. (2008a) described collaboratories as

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> … an organizational entity that spans distance, supports rich and recurring human interaction oriented to a common research area, and provides access to data sources, artifacts and tools required to accomplish research tasks. [p. 3]

Over time many other ways of talking about such organizations have emerged other than "collaboratory," such as cyberscience (Nentwich 2003), e-Science (Hey and Trefethen 2005), e-Research (Jankowski 2009), and cyberinfrastructure (Atkins et al. 2003). All of these focus on the same core idea: using networked technology to make it possible for scientists and engineers to more easily work together even if they are in different geographic locations. And, ever since Allen's (1977) pioneering work, it is well known that the threshold for describing interactions as occurring at a "distance" is approximately 30 m. So even participants in different hallways, different floors, or different buildings on the same campus face many of the challenges that will be discussed here. Of course, even greater distances incur even more challenges.

In 2000 the University of Michigan group launched the Science of Collaboratories (SOC) project, whose goal was to determine what factors differentiated successful from unsuccessful efforts at creating collaboratories. One component of this project was to catalog instances of collaboratories. This yielded the Science of Collaboratories database, which was populated over time with instances of collaboratories in all areas of science. In a recent update, Olson and Olson (2014) observed that this database had grown to more than 700 entries, covering all areas of science and many levels of scale. Indeed, in that same update, it was noted that such geographically distributed collaborations were beginning to emerge in humanities scholarship as well, facilitated by the same kinds of technologies used in science.

Despite how widespread such collaborations have become, they are still challenging to carry out. Beginning with Olson and Olson (2000), with later updates in J. Olson et al. (2008c) and Olson and Olson (2014), the challenges faced by such collaborations have been summarized in five broad areas, as shown in Table 1. Olson et al. (2008b) and Olson and Olson (2014) contain lots of details about these factors, illustrating them with concrete examples. Another recent review is Jirotka et al. (2013). As several recent reports have shown (Karis et al. in press; Bjorn et al. 2014), these challenges can be overcome with appropriate tools and procedures, which is good news for those who need to engage in such projects. But at the same time many projects struggle with the kinds of issues summarized in Table 1.

As a further aid to helping projects succeed, the Olson group has developed an online assessment tool called the Collaboration Success Wizard (hana.ics.uci.edu/wizard/). This tool is based on the factors shown in Table 1. It contains approximately four dozen questions ("approximately" because its branching structure means that an individual respondent may get a slightly different number of questions). The Wizard is administered to participants in a geographically distributed project. The Wizard comes in three flavors: one for projects that are being planned, one for projects that are already under way, and one for projects that are completed.

Table 1 Factors that lead to success in distance collaborations supported by various technologies

The nature of the work
The more modular the work assigned to each location, the less communication required
The more routine or unambiguous the work
Common ground
Previous collaboration was successful
Participants share a common vocabulary
If not, there is a dictionary
Participants are aware of the local context at other sites
Participants share a common working style, including management
Collaboration readiness
Individuals tend toward extroversion, are trustworthy, have "social intelligence," and are, in general, good team members
The team has "collective intelligence," building on each others' strengths
The culture is naturally collaborative
The goals are aligned in each subcommunity
Participants have motivation to work with each other that includes a mix of skills, they like working together, and there is something in it for everyone – not just a mandate from the funder
Participants trust each other to be reliable, produce with high quality, and have their best interests at heart
Participants have a sense of self-efficacy, that they can succeed in spite of barriers
Management, planning, and decision making
The project is organized in a hierarchical way, with roles and responsibilities clear
There is a critical mass at each location
There is a point person at each location
The project manager:
Is respected
Has real project management experience
Exhibits strong leadership qualities
A management plan is in place
A communication plan is in place
Decision making is free of favoritism
Decisions are based on fair and open criteria
Everyone has the opportunity to influence or challenge decisions
Cultural and time zone differences are handled fairly
No legal issues remain (e.g., IP)
No financial issues remain
A knowledge management system is in place
Technology readiness
The technologies fit the work
The network has sufficient bandwidth and reliability
The architecture fits the need for security and privacy
Communication tools have the richness and immediacy to fit the work
Coordination tools (calendars, awareness, scheduling, workflow, etc.) are sufficient
Everyone has access to shared repositories with sufficient access control

(*continued*)

Table 1 (continued)

Social computing (e.g., micro-contribution systems and social support) is well designed and fits the social as well as work needs
Large-scale computation fits the needs
Virtual worlds are used in appropriate ways
The choice of technologies directly considers:
Speed, size, security, privacy, accessibility, richness, ease of use, context, cost, and compatibility

An individual respondent can request immediate feedback, which is generated automatically, based on that respondent's answers. It points out strengths and weaknesses in the project and for the latter suggests remedies. At the project level, the data are summarized across all respondents and a report is prepared for project leadership. The Wizard has been used for 15 scientific projects involving more than 300 respondents. Some examples of specific projects and the kind of feedback they have provided are covered in more detail in Bietz et al. (2012).

The large sample of collaboratories in the SOC database cover many kinds of science, but it will come as no surprise that many of them involve interdisciplinary efforts to tackle difficult problems. It is now widely recognized that many important science problems require bringing diverse expertise to bear (e.g., Klein 1990, 1996; Derry et al. 2005; Fiore 2008; Stokols et al. 2010; Crowley et al. 2014). While there are some collocated scientific centers and institutes that have been designed for such interdisciplinary efforts, it is much more common that the different kinds of expertise required often reside in different locations.

While the challenges outlined in Table 1 certainly apply equally well to interdisciplinary projects, it is worthwhile enumerating the special challenges that are faced in such work, since it is clear going forward that collaboratories are a key organizational form for such projects.

There is a rich literature on interdisciplinarity and its challenges. The recent edited collection by O'Rourke et al. (2014) has many references to the challenges of such work. Here are some that are based on a discussion by Crowley et al. (2014) in an introductory chapter in that same volume and that echo various key points in Table 1.

First, different fields frequently have their own unique vocabularies. These matters are particularly troublesome when the same words mean different things in different fields. For example, different medical specialties often have different terms for the same anatomical structures, symptoms, and diseases. Even more daunting, the same term can be used in different ways in different disciplines. A project in earthquake engineering revealed that the earthquake engineers and the computer scientists attempting to build tools for them had very different meanings for "system" and "requirements" (Spencer et al. 2008).

Second, heterogeneous mixtures of participants often bring challenges having to do with styles of communication. This is only made more complex by the vast array of technologies available for communication today. Some prefer talking by phone. Others prefer e-mail. Still others like to use web-based conferencing. Users of e-mail also vary in how often they check it and how quickly they reply. Do documents get exchanged as attachments to e-mail or put somewhere in the "cloud"? It turns out the cloud today is very confusing to most (Voida et al. 2013). And emerging social media offer a bewildering array of other ways of staying in touch.

Third, different fields often have quite different practices and priorities. One example is publication practice. For instance, in many fields of computer science, refereed conference proceedings are first-class publication outlets, whereas in many other fields, conference proceedings do not count at all as archival publications. In some fields there may be only a small number of publication outlets that carry sufficient prestige to be worth using. There are also field differences in the construction of coauthor lists, both in who gets included and in what order they are listed.

Fourth, there may be major challenges when the participants in different fields come from different institutions. Universities vary considerably in their support and nurturing of interdisciplinary research. Challenges arise when researchers come from a mixture of universities, companies, or federal labs. How research practices are managed (e.g., human subjects' oversight) can vary. Bennett and Gadlin (2014) have an extensive discussion of such matters and cover five areas that are challenges to interdisciplinary work: institutional self-awareness, organizational trust, leadership, management of differences, and handling of conflict and disagreement.

There are also challenges brought on by the kinds of problems for which interdisciplinary approaches are used. As Crowley et al. (2014) note, such approaches are often used for so called "wicked" problems that "involve nonlinear causal interactions among a multitude of different elements [p. 2]." Domains like climate change, public health, and economic sustainability are difficult ones to work in. Szostak (2014) outlines the many kinds of ambiguity that tend to plague interdisciplinary approaches, often driven by the kinds of problems that are attacked this way. Examples he mentioned include different definitions of concepts, different understandings of conversations among participants, and vagueness that hides inconsistencies. He also describes how these can be handled in productive ways.

Identifying the challenges in geographically distributed interdisciplinary research is an important first step, but it leads to the question of what can be done. Fortunately, the literature has answers based on extensive amounts of research. Here are a few examples of things that have worked.

One of the things learned between the original "distance matters" paper (Olson and Olson 2000) and its later updates (J.Olson et al. 2008c; Olson and Olson 2014) is how important good management practices are. Cummings and Kiesler (2005) studied a large number of NSF-funded projects and reported two distinct findings. First, projects that were geographically distributed were frequently less successful than ones that were collocated. But second, among those that were geographically distributed, having good management separated those that were successful from those that were not.

It has become quite clear that managing a geographically distributed project has many major challenges. In part, this is because good management of such projects requires a much more proactive approach. Out-of-sight-out-of-mind problems can become very serious if proactive oversight of all the participants is not used. This can be particularly troublesome if some of the sites are small, with one or two participants (Koehne et al. 2012). Open and frequently used lines of communication are essential. There are many specific management challenges for distributed projects. Here are some of the more important ones.

A management plan is important. And it is not necessarily the plan that is important, but as Dwight Eisenhower is reputed to have said, “Plans are nothing, planning is everything.” It is interesting that most major funding agencies now require management plans as a part of grant and contract proposals, particularly for larger more complex projects. The chapters in Olson et al. (2008b) contain many specific examples of how large projects have been managed. Some have formal management committees and, in one case, actually hired MBAs with business experience.

It is well known that trust is much more difficult to engender among distributed participants (Tyran et al. 2003). While face-to-face interactions are probably the best way to do this, there are some other options that have been explored (Bos et al. 2002; Zheng et al. 2002), including using richer communication media like video and sharing nonwork, more personal information, though these forms of bridging distance can be slow to develop and remain quite fragile.

Nothing can erode a long-distance collaboration faster than decision-making processes that are invisible or biased. It is important that all involved feel that their interests are taken into account when decisions are made or resources are distributed. This is a key component of the Collaboration Success Wizard (Bietz et al. 2012).

Interdisciplinary collaborations can quickly escalate to involve serious distances that entail time zone differences as well as cultural practices. Minimal overlap in normal work days is a very big challenge. And different cultural practices, which tend to be correlated with increasing distance, can affect things like communication styles or decision-making strategies. Olson and Luo (2007) saw that such cultural differences produced serious strain on large projects such as the large hadron collider in high energy physics. Many Asians were handicapped by being far away from CERN, where the project was headquartered, and did not have access to communication or travel support that would have made interactions easier.

This is where institutional differences can become serious, particularly if intellectual property issues are involved. Olson and Olson (2000) reported attempts at the creation of multi-institutional, interdisciplinary projects that were brought down by lawyers who could not agree on how to handle such matters.

Financial issues are another area where institutional or cultural differences can arise. Olson and Olson (2014) reported on a case involving research among participants in the USA, the UK, and South Africa. In South Africa, money cannot be spent until it is in an account, whereas in the USA expenditures can be made and the funder invoiced. The solution was to arrange a loan in South Africa so money would be in the account, and the US funds were invoiced to pay off the loan.

A project of any complexity quickly generates a large oeuvre of materials: documents, data, practices, and even equipment. Who has what, and how are they shared? How is access controlled? How are such materials kept up to date? Such knowledge management issues can quickly get out of hand when projects are large, distributed, and multidisciplinary.

These management issues obviously touch many of the complexities of doing interdisciplinary research. But there are some other interventions that can also help.

If there are vocabulary issues, it may be important to create a dictionary. Olson and Olson (2000) reported several cases where time invested at the beginning of a project in doing this made things work smoothly later on. One was a large biomedical collaboration, where early on the participants realized they were calling the same things by different terms. Another was a large project on schizophrenia involving participants from many disciplines, where even talking about the same parts of the brain required clear terminology.

If there are noticeable differences in the communication cultures of participants, putting together a document that has a shared understanding about how communication will occur can be very useful. What conventions will be used for responding to e-mail? It can be very helpful for all to at least acknowledge that a message has been received even if a detailed response will be provided later.

Having clearly specified "rules of the road" can be another helpful intervention. In many areas of physics, for instance, there is an important division between theorists and data collectors. And among the latter, there can be a wide array of different kinds of instrumentation specialization. A community of upper atmospheric physicists, with NSF support, developed a document they referred to as "rules of the road." It laid out data sharing and publication practices, among other things. When in a later collaboratory phase their instruments were put on line so that they could access data flows in real time over the Internet, they realized they needed to revise their rules of the road, and they did. A different project attempted to pull together a half dozen different disciplines to study depression, but their attempt at rules of the road foundered as the practices about data sharing and publication were so different and affected participants at different stages in their careers so differently.

It is often useful to give careful thought to the kinds of technologies that will be used for communication and coordination. In Chap. 9 of Olson and Olson (2014), a wide array of technologies were reviewed, and principles for choosing among them were articulated. The four categories of technologies were communication tools, coordination tools, information repositories, and computational infrastructure. Within each of these a variety of specific kinds of tools were described.

The Collaboration Success Wizard is a tool to help with monitoring and ameliorating the challenges in Table 1. There is now a wide array of resources available to assessing and intervening in such distance collaborations. Bennett and Gadlin (2014) list many of these in their Table 17.1, including references to the resources. A couple worth explicit mention are the Team Science Toolkit developed at the National Cancer Institute (www.teamsciencetoolkit.cancer.gov) and the Toolbox

Project and its associated Toolbox Workshops (Looney et al. 2014). In short, resources to help ensure that collaborations work are available. While none of them offer guarantees of success, they all are based on research and experience that moves things in the right direction.

Conclusion

The combination of interdisciplinarity and geographic dispersion definitely presents major challenges for the participants. The extent of these problems, and whether they are unique challenges that may require different kinds of interventions, clearly needs further research. It is apparent in almost any domain of inquiry that such dispersed interdisciplinary projects will only grow, and increase in importance, as both the frontiers of scholarship and the demands of societal problems grow. What we currently know can help mitigate many of the challenges, but given the importance of such projects, constant monitoring of their patterns of success and failure is essential. Mastering these challenges will constitute a most significant accomplishment going forward.

Collaboratories are endemic organizational forms that exploit the emerging cyberinfrastructure, and many of the challenges to making them successful are now well understood. Interventions are available. They provide a kind of organizational resource that can make interdisciplinary projects work (Finholt and Olson 1997). But success will require careful ongoing attention.

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