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Scientific Collaboratories as Socio-Technical Interaction Networks: A Theoretical Approach

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Abstract

Collaboratories are laboratories where scientists can work together while they are in distant locations from each other and from key equipment. They have captured the interest both of systems developers and of science funders who wish to optimize the use of rare scientific equipment and expertise. We examine the kind of conceptions that help us best understand the character of working relationships in these scientific collaboratories. Our model considers technologies as Socio-Technical Interaction Networks (STINs). This model provides a rich understanding of the scientific collaboratories, and also a more complete understanding of the conditions and activities that support collaborative work in them.

Introduction

We are in the midst of a revolution about the expectations of how IT can substantially improve communications and collaboration among scientists, as well as with professionals and broader publics. From the beginnings of the Internet, funding for IT infrastructure is frequently justified in terms of speeding up and widening access to scientific communication. Many of the expectations are based on conceptions of high speed telecommunications enabling information to move rapidly and relatively inexpensively “anywhere anytime” – thus enabling low cost and widely available electronic journals, preprint servers, collaboratories and so on.

These expectations have both fostered and conditioned the development of a wide variety of new scientific collaboratories. The term “collaboratory” is often used to refer to laboratories where scientists can work together while they are in distant locations from each other and from key equipment. Many of these new collaboratories have been developed and even more are in the planning stages. However, the usage of these collaboratories varies widely, and many are not used to the degree and in the manner in which they were intended.

The character of the working relationships in these collaboratories are strongly shaped not only by social relationships – such as those between scientists and technicians, but also by relationships between actors and technologies. For example, deep expertise may make a technician a desirable collaborator. Scientists may be constrained in their ability to make effective use of a collaboratory by the tools in use at their institutions.

In this research note, we introduce a theoretical model that will help us understand (1) the character of working relationships, both during development and during routine operations of a scientific collaboratory; and (2) the social relationships that enhance sustainability of a collaboratory within a community. We find that this theoretical model, Socio-Technical Interaction Networks (STINs) ¹, provides a richer understanding of the scientific collaboratories, and also a more complete understanding of the conditions and activities that enhance the sustainability of a communications forum within a field.

Methods

We used two different methods in performing the research that led to this article: documentary interpretation and semi-structured interviews. First, the research team read exhaustively documentation about scientific communications forums and collaboratories in specific.

In order to build this model, the research team conducted in-depth semi-structured interviews with some of the key shapers of these communications forums. We interviewed shapers of HEP collaboration web-sites at HEPLAB and a materials science collaboratory, MatterLab, (as well as other scientific communications

¹ The STIN approach is inspired by actor-network theory (ANT), as developed in Latour (1986), as well as our own prior research about ‘web models’ of computerization (Kling & Scacchi, 1982; Kling, 1987; 1992). ANT is an ontology that maps out the practice of science and technology in terms of enrollment and mobilization of supporters of a particular scientific claim or technology. The advantage of ANT for IS is that it provides insights about the feasibility and sustainability of particular scientific collaborative systems. However, it has two primary weaknesses, from an IS perspective: (a) it is more useful in analyzing development of new systems than routine operations, in which explicit mobilization and enrollment may be less important; and (b) it provides little guidance on how to draw the networks – which kinds of enrollments matter. The STIN approach is an attempt to correct for these weaknesses, while still retaining ANT’s analytical power.
Socio-Technical Networks

From Technical to Socio-Technical

Conventional theories of technologies portray them as tools whose adoption by organizations is based on norms of rationality and technical efficiencies. Different ways of configuring technologies in practice are of relatively minor significance. In the case of scientific collaborations, the conventional analyses emphasize the rapidly increasing price/performance of hardware, the declining size and weight of equipment, the ubiquity of telecommunications to help people to move data readily within and across organizations. The conventional theories tilt towards economic and technological determinisms. For example, some scientists believe that the experimental high energy physics working article (e-print) server at Los Alamos national labs (Arxiv.org) is the model of publishing that will sooner or later be followed by all of the sciences: it is “just a matter of time” (Kling & McKim, 2000).

Careful empirical research studies about ICTs have found that “almost identical technologies” are often configured very differently in practice. It is common for preexisting social arrangements to influence these configurations. A “social shaping of technology” perspective suggests caution in trusting deterministic claims. In addition, each social group may have to locally configure ICT’s to use them most effectively. What are claimed as “best practices” may work well in some organizations but not others. Thus local R&D costs can remain relatively high and the overall costs of using new ICT’s may not fall rapidly. There are important economic and social consequences in the differences between these kinds of predictions.

These theoretical differences are of major practical consequence. In the case of ICT’s (broadly), the conventional theories lead us to emphasize the rapidly increasing price/performance of hardware and to anticipate media convergence. Some go farther and “believe that the paper document is dead; we are just not aware of it yet (Wulf, 1999).” Further, one can expect that a few well-crafted pilot projects – done almost anywhere -- can help to establish “best practices” that everyone else can follow. A first stage of social learning about new communications forums can be exploratory and costly; however, subsequent uses elsewhere can be imitative and relatively inexpensive.

The Layer-Cake View of Socio-Technical Systems

Some analysts have been using the term “socio-technical” informally to understand collaboratories and other IT applications. There are two common uses which differ considerably from ours. The first is that IT applications are “technologies” with social consequences. Technologists build applications; social scientists then study their consequences for work, organizational forms and other social behavior.

A second common use is reflected in some of the discussion of collaboratories (e.g. NRC, 1999). In this view, collaboratories can be viewed as layered systems. The bottom layers are various technologies, such as computer networks and specific applications. The “tool sets” of the collaboratory are “the technical layers.” The “socio” arises when people use the collaboratory. The behavior of the participants should be understood as “socio-technical” because of the strengths and limitations of the tool sets at any given time. This conception can play a useful role for some purposes; but also separates “socio” from “technical” by virtue of how the layers are conceptualized. Even so, this conception has undergirded some interesting and important research (e.g. Galegher, Kraut and Egido, 1990). We refer to this conception as a “layer cake” in which technologies compose the primary layers and social life abounds between the people who come to party with each other and consume the cake.

In contrast, Myers (1999) characterizes his Environmental Molecular Sciences Laboratory (EMSL):

Before deciding which tools to use in their work, researchers first need to consider what occurs when they do science and how collaboration can help. Setting up a collaboratory is not simply a matter of running a remote experiment. Remote control software may let participants perform the experiment, but they will also need access to the sample preparation procedures, instrument settings, and other information usually recorded in a local paper notebook today. Before the experiment can be considered, potential participants must discover the remote resource, understand its capabilities, contact the local
researchers, develop trust, and perhaps receive training on a remote instrument. Even if the researchers decide to visit the EMSL to conduct the actual experiment, they can meet people, understand procedures, and learn about the instrument before they arrive. Remote researchers must also find effective techniques for analyzing the data and consulting with co-researchers in writing up publications. Because scientific data are often complex and multidimensional, researchers will need to be able to confer with local researchers familiar with analysis of data from EMSL instruments.

Myers characterizes a collaboratory in which scientists who wish to use it have to understand the instrumentation, learn how to prepare samples for it, and perhaps have the instruments reconfigured. This learning requires help from scientists who have significant responsibility for selecting, configuring and maintaining specific instruments. In the layer-cake model, there is no one “in the collaboratory” before its users arrive and after they leave. In Myers’ account, however, each major instrument has a scientist at its side before “users” come and after they leave. Further, in order to utilize instruments in a collaboratory, a scientist (or team) at a remote location have to develop social relationships, such as trust, with the scientists who know the instruments and who can be viewed as ‘inside” the collaboratory.

In our view, the concept of socio-technical should be used to refer to more integrated conceptions of the interaction of people and technologies. In particular, what are referred to as technologies are developed within a social world and supported by technicians and others with specialized skills.

What Are Socio-Technical Networks?

While few scientists have direct experiences with collaboratories, academics are familiar with oral forms of scholarly communication and its alteration by electronic communication. So this makes a good example for explaining one view of socio-technical networks. Amplifiers in lecture halls, video conferencing, and videotape alter the nature of audiences that scholars can reach, and also shift the relationships between those audiences and lecturers/speakers. These electronically enhanced forums do not simply provide "more communication," but also alter the ways that people speak and interact. The speaker may have to work in a special conference room and be separated from local participants by complex equipment (thus altering local interactions). As the audience scales up in size, or moves out in space and time with real-time video or asynchronous-video-tape, the informal give and take between speakers and listeners becomes more difficult (in contrast with the smaller face-to-face seminar). On the other hand, people watching a videotape may privately replay sections to enhance their comprehension, while in a face-to-face meeting they may have to ask questions (that might also embarrass the speaker or questioner).

Voice-based face-to-face conference, video conferencing, and videotape are not simply equipment. They shape scholarly communications as socio-technical networks in which social characteristics such as controls over access (via pricing and distribution channels), and social protocols for regulating discussions between speakers and audience also influence character of scholarly communications. It should be noted that the use of the term “network” in this discussion is primarily metaphorical; the participants in socio-technical networks may or may not be connected via various technological or social networks.

These socio-technical networks are heterogeneous since they bring together different kinds of social and technological elements -- cameramen their cameras, and speakers; editors and their technologies; copyright laws and perhaps even lawyers; funders and their budgets; producers and their time schedules into a 'seamless web'.

The nature of videotape pricing and the distribution channels can lead to minor or huge expansions beyond the original conferees. Despite scholars' potentially broader access to conference talks via videotape distribution, a face-to-face conference is different from a videotape collection of its talks because of the diverse informal discussions and important social networking that conferences support. The face-to-face conference and the videotape collection are different scholarly communication systems with overlapping capabilities, but which also support very different forms of scholarly communication.

Note that socio-technical networks (and socio-technical interaction networks in particular) are not just a variation of social networks. In most social network approaches to computer-mediated communication (Wellman, 1996, is a particularly good example), the network nodes are people, and the links represent various forms of social interaction, which may or may not be computer mediated. The nodes of socio-technical networks, on the other hand, include not only people, but also organizations, standards, technologies, institutions,
and artifacts. Socio-technical network approaches focus therefore not just on the technologies of communication but also on the technologies of work, and open up questions such as how technological mediation is changed when different technologies, standards, and architectures are put into play.

Generating Socio-Technical Interaction Networks

A significant problem faced by sociotechnical analysts is that of how to figure out what belongs in the network and what does not – in other words, how to generate the network. The STIN approach calls out several different social interactions as being generative of sociotechnical networks.

These types of social interactions include: resource dependencies and account-taking. Resource dependencies create networks that include groups such as funders and grantees, scientists who develop collaboratories (insiders) and offsite scientists who utilize them (outsiders), employers and employees, and journal publishers, editors, reviewers, and authors. Constructing networks based on resource dependencies highlights several important themes, including the political economy of a forum, various kinds of hidden (articulation) work, and network extension through institutional linkages. Account-taking links an actor to others who serve as “reference points”. Scientists may take account of their peers in competing laboratories, the program directors who review their proposals and scientific progress, and the editors and reviewers of conferences and journals who influence the visibility of their research. None of these other scientists may be formal participants in a collaboration; yet they are likely to have some influence on the problems chosen, the ways that they are approached, the instruments used, the pace and scheduling of a collaboratory’s work, and the downstream forms of publication (as well as the nature and number of communications between the direct participants in a collaboration).

STIN-based Analyses

Explicit STIN models have been applied to understanding the IT support of scientific research teams (Kling, 1992) and understanding the relative viability of early collaboratories within model organism molecular biology (Star and Ruhleder, 1996). Implicit STIN models have undergirded studies of IT applications failures (e.g. Markus & Keil, 1994). STIN models have also been applied to understanding the character and development of electronic documents (Braa and Sandahl, n.d.) and Internet standards (Hanseth and Monteiro, 1997; Monteiro, 1998; Monteiro, in press). These studies illustrate that STIN concepts are often understood informally in some professional IT communities.

Our interests in framing an alternative to the Layer Cake Model of ICTs are illustrated by the social interactions that energize collaboratory life that are briefly sketched in these accounts by Myers and others. These social and technical interactions seem to shape the work of collaboratories and their intellectual location in their own scientific fields. They are anomalies relative to the Layer Cake Model, but are central to the Socio-technical Interaction Network models that we examine here.

Conclusions

We have articulated an alternative to the layer-cake model of ICTs, STIN-based model that helps to better understand some of their key aspects. In Kling, et al. (2000), we examined in more detail how STIN models help understand important behavior in a materials science collaboratory (MatterLab) and in a HEP collaboration (CONVEX). We found that, like UARC/SPARC (Olsen, at. al, 1998), the CONVEX collaboration existed prior to the development of online environments. In contrast, MatterLab was developed to help foster some new collaborations. Styles of scientific work differ across the sciences, and within them. For example, we expect different kinds of work practices and communications in small teams (MatterLab, UARC/SPARC) than in gigantic collaborations of 1700 physicists, such as ATLAS and CMS at CERN. Most importantly, we have found that STIN models help to highlight important behavior which is backgrounded or ignored with Layer Cake models.

One of the important consequences of adopting an STIN-based model is that it becomes clear that radical improvements in IT developments will not wash away the issues of sustainability and integration into a social world. For example, as the once-cutting-edge scientific instruments at MatterLab became more common elsewhere, the ability of MatterLab’s scientists to be effective collaborators was more central to the collaboratories’ scientific productivity. Social advances, such as developing workable co-authoring agreements are as important as having great communication environments.

Second, STIN-based analyses inject social analysis into all phases of planning, development, configuration, use, and evolution of a collaboratory, rather than merely at the beginning (in determining user “requirements” of a system), and post-deployment (in determining the social “impacts”) of the system. The examples of the MatterLab and HEP collaboratories help illustrate different types of
social relationships foregrounded by an STIN-based analysis that are important to the use, sustainability, and evolution of collaboratories. The HEP collaboratories illustrate the extent to which working scientists are sensitive to selectively releasing information to others (and thus the importance of security protections as well as documentary and data sharing).

Third, the relevant STINs are not just constituted from technical tools and direct participants in a scientific teams. The weaker ties of competition with other teams that use better, lesser or different instruments and research designs can influence the willingness of a team to work with a specific collaboratory.

Fourth, the term “user” flattens the interactions of the scientists who work with a specific collaboratory. STIN models portray them as social interactors whose work and communications are influenced by their locations in larger scale networks of scientists, funders, publishers, etc. The way that STIN models encourage IS researchers to move from “thinly” depicted users to socially richer characterizations of people working and communicating in complex multivalent socio-technical networks that extend well beyond immediate workplaces and the most tightly coupled teams, may be most important.

All of these behaviors would be hard to anticipate from the Layer Cake Model of ICTs. We suggest that future discussions of collaboratories and other ICTs, should be informed by STIN models. Their heuristic of seeking the social elements of technical formations and the technical supports for social life opens up important lines of inquiry to better understand these complex practices.

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