

Analyzing distributed communities for design: Methods for revealing distributed and embedded cognitive work

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Introduction

This paper proposes integrating disparate methods for analyzing collaborative activity across distributed cognitive systems. This approach was developed specifically to support analysis of intellectual collaboration in large, open-ended distributed organizations such as scientific research communities. This approach offers at least two significant uses. One, we expand the scope of inquiry to enable ethnographic research to address a wider range of collaborative activity within a single work domain studied. Two, expanding the range of collaboration redefines how we view the nature of work, opening up new opportunities for system design and work innovation. Another benefit of integration is to realize scaling the unit of analysis from individual tasks to inter-organizational collaborative work.

In such distributed communities, individual work practices encompass collaborative *goals*, but the collaborative *work* remains invisible to observational methods such as ethnography or contextual inquiry. We adapt cognitive work analysis (Vicente, 1999, Rasmussen, 1994) and activity theory (Nardi, 1996, Cole and Engeström) to analyze ethnographic and contextual interview data to reveal collaboration within the scope of activity, and within the ecology of the work domain. These two frameworks have not been explicitly joined in other published research, but they offer complementary analyses of distributed cognition in work practice. While studying activity reveals the individual's relationship to work community and motive, work domain analysis accounts for structural drivers and constraints. Activity theory describes the community's practices, and shows us how and why actions contribute to collaborative projects. Cognitive work analysis shows us the bigger picture, how and why the activity itself fits into a large distributed community.

The paper explores the integration of these cognitive work frameworks as used in current research. We approach the question of collaborative activity from two directions, from the work domain to the individual, and from the individual out to collaborators in a distributed community. Activity theory analysis enables abstraction from the individual extending to their collaborative actions. Cognitive work analysis supports a top-down abstraction method that resolves units of analysis at the range of levels in which people interact. Both of these analysis frameworks are theoretically compatible with distributed cognition, which we analyze "within levels" based on observations of collaborative work practices and their associated cognitive artifacts.

Case Study: Scientific Research

Many socio-technical systems can be conceived as *distributed communities* for the purposes of understanding the social systems influencing and interacting with the whole system. The world of contemporary scientific research offers an example of a distributed community with collaborative relationships at every level of analysis. This model is based on cognitive ethnographic research

conducted in 2002-2003 at two North American universities, in the life sciences fields of molecular biology and pharmacology. An activity theory framework was adapted to analyze collaborative work, specifically focusing on the collaborations involving the development, use, exchange, and communication of scientific research articles.

While activity theory provides a hierarchical model of context, the contexts in practice do not show up “ready to fit” into the distinctions of activity. To identify appropriate levels of collaboration (and from which to draw inferences of motivating drivers of activity) we organized contexts into four categories by individual and collective dimensions of use.

Context	Individual Information Use	Collaborative Practices
Scientific Discipline Environment, largest context	Research within the context of publishing or theoretical contributions to discipline.	Collaborative projects, workshops, panels, etc. specifically aimed at discipline development.
Institution / Department Context for research project	Faculty, students research contributions to programs in department or university.	Faculty and students working in collaborations toward internal programs or department projects.
Research Program / Project Activity unit of analysis	Individual information behavior supporting research goals over duration of project.	Individuals collaborating on research projects, using and sharing distributed resources in defined research efforts.
Task Actions, information tasks supporting activity	Individual information seeking, use, and cognition. Analysis of information tasks.	Information tasks performed in interaction and collaboration with other individuals.

Hierarchy of research activity contexts.

A four level activity hierarchy shows *research program* or the project as the unit of activity analysis. Two levels of context for this activity were identified, the institution and the discipline. The task level, while not a *context* for activity, specifies behavior at the *action* level.

To analyze findings in the context of collaborative work, two dimensions of individual and social were used as way to distinguish between subject-centered analyses and community-centered descriptions. To understand information behavior in actual research projects, the collaborative dimension captures the “division of cognitive labor” in research projects. This model also enables the navigation of contexts in data analysis and interpretation. We can assess the relative influence of motivations and drivers from different communities in the scientists’ world, the *disciplinary* community, the department, or the program’s community.

Scientific Discipline

The discipline was the largest level of context for analysis of collaborative information behavior. Our research selected a single-disciplinary sample (molecular biology) and a (largely) interdisciplinary field (pharmacology) to understand two types of disciplinary research contexts, to consider both trends within the larger context of life sciences.

Institution / Department

The practice of scientific research is situated within the real-world context of an academic department and/or a sponsoring institution. Our field studies sampled from two different sites to uncover possible differences in the setting or institutional environment, between a small research

center and a large university department. While the local research practices differed greatly between the two settings, institutional drivers and constraints were largely identical.

Research Program / Project

The central unit of analysis was the research project as *activity*, focusing on information practices necessary to accomplish experimental research. Conducting experiments and publishing articles are often conducted, and observed, as individual work practices. The project or program gives meaning and direction to the experimental findings – the “edge” of this context is described by the lifecycle of a research project, where these actions are seen as collaborative work in the project context. Running experiments and writing papers are then found to be complex, distributed cognitive tasks facilitated by constant creation and exchange of cognitive artifacts. But many participants in this process may not even recognize the inherent collaboration in these practices, since most actions appear as individual tasks.

Task

In the activity system, tasks are analyzed as *actions*, not as a context for action. Cognitive science studies often adopt the “user’s task” as context for information use. Analyses of search behavior, and other microbehavioral analyses, adopt the user’s immediate task as its motivating context. The task itself represents a concrete goal state, inhibiting inference beyond task unless we locate the task within larger goal states and work activity.

We represent information tasks as *actions*. Activity theory moves the context “higher,” consistent with the activity unit of analysis, which embeds activity in the social and institutional contexts of the academic research institutions and systems. Information tasks are not analyzed differently; they are defined as any individual action using an information resource to seek and acquire information artifacts. But instead, the task is located as an individually-directed action, inextricably bound with the work practices of research activity. Activity theory builds upon a constructivist (Vygotskian) theoretical background; with the principal difference of explaining information behavior in terms of a cognitive work practice in an activity context.

In conclusion, this model of contexts frames upper and lower boundaries of the research project activity system, defined by tasks as individual actions and Institution as the immediate driving and constraining environment. While *discipline* serves as a major context for research, and context for the objective of discovery, it is a larger, secondary context for a research *project*.

Four types of collaborations were categorized, each representing a different type of relationship or network.

Collaborations of interest – Internal collaborations of learning and research form as networks, as aspects of larger research projects are shared among investigators with specific interests. These may be organically distributed (as members have time and interest) or specifically allocated networks (by investigator or research lead).

Collaborations of expertise – Non-overlapping knowledge, knowledge of literature, authors, and methods in the designated subdiscipline can be delegated and drawn from as necessary during different phases of research cycle.

Collaborations of facility – Equipment and facilities not available locally are often shared with larger research centers or other institutions as part of collaborative arrangements.

Collaborations for shared goals – Similar or overlapping work within the peer network may be combined for specific projects and goals, e.g. to strengthen a grant or research paper, leading to a better publication or farther-reaching proposal.

Methodology

A multi-method research approach was developed over two field studies, to gather field data, organize data, and analyze/interpret findings. Drawing from several techniques allowed observations to follow the participant’s natural line of work practice, and increasing the likelihood of valid, useful data by triangulating methods. The following research interventions were used as a complete field research approach:

1. Semi-structured in-depth interviews
2. Information research task diaries
3. Information services walkthrough interviews
4. Information artifact use / observations

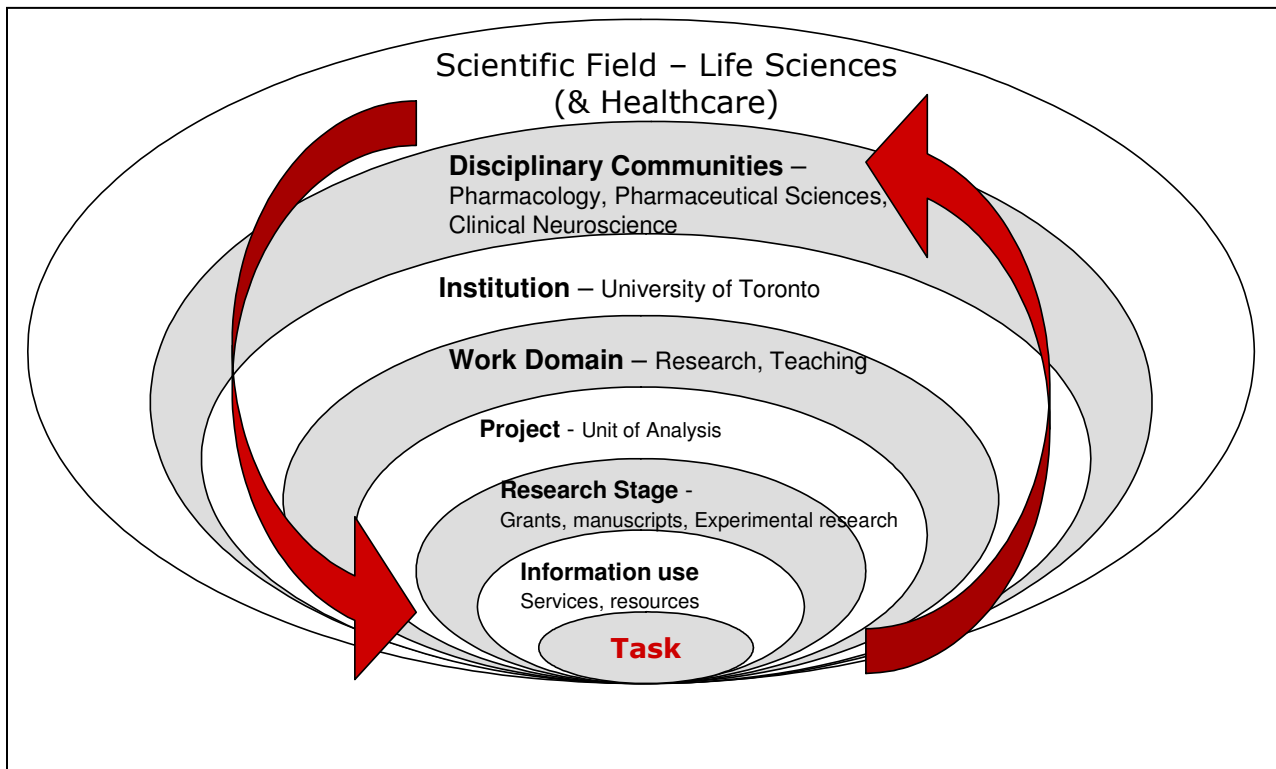
Our aim in analysis was twofold, with one goal suited to CWA and the other goal suited to activity theory. The analysis required to understand the ecological factors of scientific collaboration in practice (work environment, institutional drivers and constraints, disciplinary context) promoted the holistic ecological approach of CWA. The analysis required to understand individual and small-group collaboration (research discovery, workgroup behavior, individual motivation, and information use) suggested an activity theory orientation. As these research goals and methods were known in advance of the study, the data collection protocols were designed to answer our pre-determined questions according to both analysis approaches.

This position paper does not discuss the activity theory approach for this study, which has been presented in prior workshops and papers. The integration of the CWA method was not presented in prior discussions, however, and is the focus of this position paper.

Following a cognitive work analysis approach (Vicente, 1999), using an abstraction hierarchy, we define 8 levels of analysis as described below in the table and represented in the figure below. The focus unit of analysis was *information activity in research projects* (levels 5-6), consistent with the activity theory analysis used in prior studies.

Level of Analysis – Abstraction Hierarchy	Focus of Study
1. Scientific Field	Life Sciences
2. Disciplinary Communities - Population	Pharmacology Pharm. Sciences Neuroscience
3. Institution – Context, Environment	University of Toronto
4. Work Domain – Cognitive work domains	Academic Career, Research Practice, Teaching
5. Project - Unit of Analysis, Information Activity	Research and educational projects
6. Research Stage – Phase of Activity (over time)	Research Activity: Grant proposals and manuscripts, Experimental research
7. Information Intention - Strategy of use	Information use, services, resources
8. Individual Action – Tasks observed	Information behavior, specific actions, searches

The full matrix of the abstraction hierarchy showing the means-ends and functional relationships are not described in this paper. Instead, a high level diagram below illustrates how the model is viewed dynamically. This hierarchical view should be considered a series of levels of ecology, with the task (at bottom) subject to the relationships of the ecologies in which it participates and inherits qualities of work practice. While not “determined” as such, tasks and the activities they support are coordinated by each ecology in this larger environment. Tasks may also be seen as supporting objectives of activity and of the work domain and institution. Tasks also participate in *horizontal* ecologies, such as the information ecology across all communities in this academic domain.



Conclusion

Analytic approaches such as Cognitive Work Analysis, means-ends abstraction hierarchies, and cognitive engineering promote a systemic assessment and deconstruction of ecological and cognitive factors. But cognitive engineering has not been typically employed for research inquiry into collaborative work in self-organizing intellectual activity. Cognitive engineering has been developed in process control domains, and the methods have not found purchase in the analysis of intellectual work such as research or product development. But much of the process in some work domains lies embedded in the organizational infrastructure. While not obvious or even observable within the context of *activity*, the ever-widening rings of context show multiple ecologies that drive activity and individual behavior in domains such as scientific research.

But while useful for their intended purposes, analytic decomposition can break down in the attempt to understand and describe self-organizing collaborative activity such as found in intensional communities and intellectual collaboration. CWA does not help us understand work at the activity level (and neither, I might argue, does cognitive task analysis, which is too granular for collaboration). The various uses and motivations for collaborating, the objectives of team activity, the communities that form and disband in the occupational networks are better understood through a method such as activity analysis.

And while activity theory and distributed cognition can be adapted to reveal the embedded organizational drivers and constraints, their units of analysis limit the scope of inquiry and interpretation to the socio-technical or functional cognitive system “at hand.” CWA might be considered an analytical approach to locate the embedded structures that contextualize activity. Sociological analyses such as boundary objects (Star, 1995, Star and Griesemer, 1989) also offer significant research power toward understanding ecology and embeddedness. Yet these two systems of inquiry are *highly* dissimilar. Yet I propose that we are studying the same “objects” and “systems” and artifacts in these dissimilar approaches. By carefully abstracting from observations to retain the wholeness and meaning of observations within each type of ecology (work, practice, disciplinary, institutional), we can draw forth meaningful interpretations of the whole system in which activity is embedded. We have also used these methods for deriving technology innovation proposals that draw directly from needs expressed in the analysis. Finally, we should aim to develop a robust methodology applicable across domains, affording analysis, insight, and even generalization into the ecologies of practice, community, and work domain.

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