Identifying Mediators of Socio-Technical Capital in a Networked Learning Environment

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Abstract

In addition to supporting immediate instructional objectives, online learning environments can enable participants to gain value from a network of scholars and resources. This potential value in a technology-mediated network has been termed *socio-technical capital*. Our software, Prometheus, is being used to support online university level education and teacher professional development under an open community model inspired by this idea. The analysis reported in this paper examines the extent to which people who come to the online environment for instrumental objectives such as taking a course encounter persons or products of others from outside their course workspace. Various digital media available in Prometheus—discussions, resources, user profiles, and wiki pages—are compared in terms of how they support these encounters. Results show that there is appreciable bridging across classes and programs, and that the effectiveness of media for socio-technical capital depends on whether they are owned by task-specific workspaces.

Keywords

Online learning, bridging, boundary spanning, socio-technical capital.

Introduction

A tradition of discourse in learning communities goes back to the earliest efforts at online education (Feenberg, 1993; Hiltz, 1986). Following this tradition, asynchronous learning networks were envisioned as "networks" not only in the technological sense, but also in the social sense: networked learners were seen as resources to support each others' learning (Mayadas, 1997). A feeling of social belonging improves students' online learning experience (Wegerif, 1998), and with proper scaffolding, learners can engage each other in knowledge construction (Aviv, Erlich, Ravid, & Geva, 2003; Hansen, Dirckinck-Holmfeld, Lewis, & Rugelj, 1999). Likewise, our approach to university level education values students building on each others' work and seeks to build a sense of community that transcends individual courses. We support several overlapping learning communities consisting of graduate level programs in a department of Information and Computer Sciences, and an interdisciplinary Communication and Information Sciences Ph.D. program. Students and faculty in these programs participate in multiple nested and overlapping groups and are members of a larger community. Yet, this reality is not well supported by some online learning environments. As they were implemented in our institutional context when this work commenced, systems such as WebCT and Blackboard isolated students from each other. Students encountered materials and each other in individual course contexts, but the software was not designed for group collaboration and the inter-course space was not emphasized. This "silo" approach (isolating classes) is somewhat intentional: institutions need to restrict access to tuition-paying students, and prevalent pedagogical approaches rely on controlling the order in which information is revealed to the student and view building on others' work as a form of "cheating". Unfortunately the silo approach can inhibit pedagogical approaches that can be conducive to learning, such as collaborative learning (Dillenbourg, 1999; Webb & Palincsar, 1996), apprenticeships (Lave & Wenger, 1991), and interdisciplinary/transdisciplinary collaborations (Derry & Fischer, 2005). In response to this need, we designed a software environment, disCourse (discourse.ics.hawaii.edu), to support individual courses while also allowing for serendipitous discovery of other persons, ideas and resources in the larger social network. We are now studying ways in which participants benefit from persons and resources in contexts other than the original course to with they were assigned, and how the various digital media available in our software support such forms of networked learning. This paper reports our second analysis addressing these questions, improving on a preliminary study reported in Suthers, Chu & Joseph (2009). We begin with a discussion of the concept of *bridging socio-technical capital*

and its relationship to potential mediators in our software environment. Then we describe a method for tracing out bridging socio-technical capital in log files, and report on the results of our analysis and its implications.

Background

Bridging socio-technical capital

Long before the recent Web 2.0 explosion of "social networks" as a specific genre of software application, researchers have studied social networks in online learning contexts (Barab, Kling, & Gray, 2004; Rekkedal & Paulsen, 1989; Renninger & Shumar, 2002). Participants often come to such environments for an instrumental purpose, for example to participate in an online course or professional development activities. Bridging (Granovetter, 1973; Simmel, 1971) or boundary spanning (Levina & Vaast, 2005) between these instrumental groups can realize the potential synergy of the larger social network.[1] Computer mediated communication enables each person to participate in a much larger number of casual relationships ("weak ties"; Granovetter, 1973) than is possible through face-to-face interaction (Donath & Boyd, 2004). A network of weak ties provides access to more potential collaborators and novel information beyond what is available in one's immediate strong tie circles (Granovetter, 1973). Putnam (2000) calls these resources for potential action *bridging social capital*. Properly designed social technologies increase this kind of social capital. Since the capital in socio-technical networks partially resides in how the technology enables the social network, Resnick (2002) refers to it as *socio-technical capital*. Combining these ideas, we have designed for *bridging socio-technical capital* in two learning related applications: one for teacher professional development and another for university level education. In these online environments, a number of people who may have something in common are participating in task-specific workspaces that are embedded in a shared virtual space. Our objective is to design this space to offer affordances for the sharing of something of value between participants beyond the specific instrumental objectives that brought them to the workspaces (e.g., professional development activities or taking a course).

Prometheus and disCourse

The software environment studied in this paper was first developed in the context of a technology-supported systemic reform effort called Hawai'i Networked Learning Communities (HNLC.org, Suthers et al., 2004; Suthers, Yukawa, & Harada, 2007), in which we developed a "community of reflective practitioners" approach to professional development (Yukawa, Harada, & Suthers, 2007). Recognizing that school teams can benefit from the state-wide community, we designed to enable discovery of value in the larger social network that forms by embedding smaller groups with well-defined purposes in a common space (Joseph, Lid, & Suthers, 2007; Suthers et al., 2004). Realizing that the community-oriented nature of HNLC.org also suited our approach to university education, our team generalized the software to a code base called *Prometheus*, and used this to implement HNLC.org (teacher community) and disCourse (university community) instances, as well as other instances. (Prometheus is not related to the open source project suppressed by Blackboard.)

A Prometheus instance contains the following resources for collaboration and community. Any user, without logging in, can access *stories* that are posted on the home page. When a story is posted, all members receive an email notification. The general public can also access a database of searchable metadata on web-based *resources*. Logging in, a registered user has additional access to member profiles, discussions, and workspaces. Contributions such as messages, resources and stories are tagged by a link to the *profile* of the person who posted them, enabling members to learn more about persons who may have similar interests. Member profiles provide contact information and link to each member's workspaces and discussion postings. *Discussions* are web-based threaded discussions, displayed in context to facilitate referencing: one can open up multiple sub-threads at the same time on one page, and when one replies to a message the reply composition box is embedded in the context where it will ultimately appear, with all the currently open messages also visible. Discussion postings include a link to a record of who has read the message. *Workspaces* include many of the other available resources of the environment and add a few features (Figure 1). The intention is to collect in one place everything a workgroup (e.g., class, or teacher team) is using to support its work. Each workspace has a main area in which the current object being viewed or edited is displayed, plus various tools and resources listed on the left and right hand sides. The items accessible on the sides and displayable in the main area include wiki

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[1] Some literatures define "bridging" and "boundary spanning" in terms of membership in two or more groups. In this paper we use the terms synonymously for participation outside of one's assigned groups, to be explained.
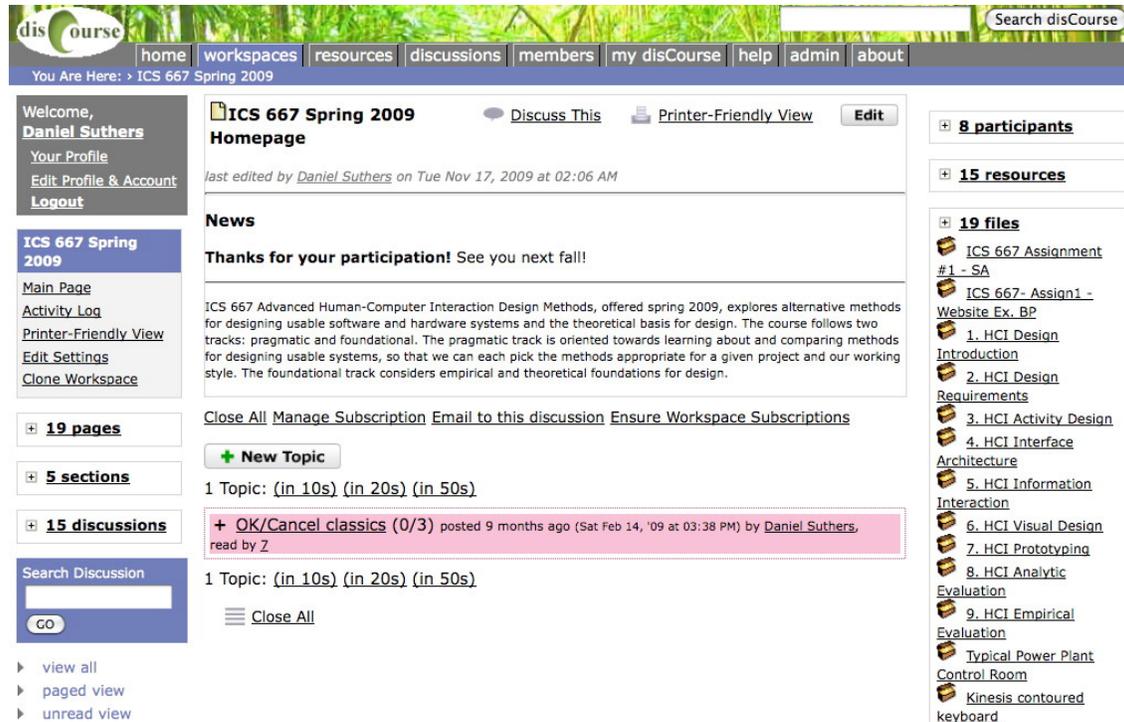
Figure 1: A disCourse workspace.

pages, discussions, participant profiles, resources and uploaded files (both in the resource database), a synchronous chat tool, and links to sub-workspaces ("sections"). Wiki pages and discussions are paired (center of Figure 1): each wiki page can have a discussion attached to it where participants can discuss the contents of the wiki page as they edit it, and each discussion can have a wiki page at the top for stating the purpose of the discussion, posing questions, summarizing conclusions, etc. In either case, the motivation is "artifact centered discussion:" learning and work often require coordinated talk about artifacts while also modifying them (Suthers, 2001). In summary, the digital mediators by which users may find value in the larger social network include lists of recently contributed resources and recently active workspaces and discussions on the home page; lists and tabs under which one may browse and search available discussions, resources and workspaces; and links from artifacts to contributing and reading members.

Method

This study addresses the following research questions: (1) To what extent do people who come to the online environment find potential value that derives from the presence or products of others outside the workspace in which they pursue their instrumental objectives? (2) By what technological mediators do they find this value that we might strengthen and exploit further? What potential mediators are underutilized? Our method is based on automated analysis of log files. Below we discuss how we operationalize bridging socio-technical capital, conceived of as access to potential value derived from the presence of others.

Operationalizing potential value

Our analysis is based on the simplifying assumption that a digital artifact has *potentially* offered someone value if that person has accessed it. We include read access and write access where it is applicable. This definition is clearly inadequate with respect to whether the individual involved actually felt that they were gaining value, but it is not feasible to interview participants at the scale of this study, nor plausible that they would remember every access event. For purposes of comparative analysis, such access events provide an upper bound on

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potential value. Since we are concerned with *socio*-technical capital, we need to restrict consideration to artifacts that derive from the presence of others in the social environment. Specifically, we consider four kinds of digital artifacts that may be created by one person and accessed by another: discussions, resources, user profiles, and wiki pages. The analysis reported here operationalizes potential value as follows: one gets socially-derived value from a discussion if others have posted to the same discussion; from a resource that someone else has provided; from viewing someone else's profile; and from a wiki if others have edited it.

Capturing artifact-mediated associations in associograms

A simple yet powerful way to capture, structurally as well as quantitatively, the relationships that derive from participation in a social space is through *sociograms*: graphs in which vertices are persons and edges are "ties" between persons (Scott, 1988; Wasserman & Faust, 1994). Since we are concerned with socio-*technical* capital and with the mediating role of digital artifacts, we treat technological artifacts as "actants" (Latour, 2005) that can participate in ties just as persons can. Following Latour, we call these ties "associations" to emphasize that they do not require that there is an interpersonal relationship between the persons involved:

Figure 2: An associogram.

people can share socio-technical capital via their mutual involvement in an artifact without necessarily knowing each other. We represent networks of mediated associations with bipartite graphs between persons and artifacts (a type of affiliation network). The edges are directed arcs to indicate direction of contingency: an arc from an artifact to a person indicates that the person has created the artifact; and an arc from a person to an artifact indicates that the person has accessed the artifact. Thus, an association between two persons is represented by a path of two arcs passing via an artfact. We call these actor-artifact graphs "associograms" to distinguish them from sociograms. Figure 2 shows a simple example. The two-arc pathway shown represents a mediated association. Resource 13 is contingent on user 14 (its creator), and user 12 is contingent on the resource by virtue of accessing it. The dotted line indicates a spontaneous association, discussed next.
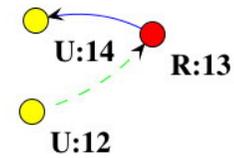
Restricting to spontaneous associations

In order to identify socio-technical capital gained beyond mutual participation in a class or other task-oriented context, we make the following distinction. Associations arising between users participating in a workspace to which they were assigned are called *assigned associations*. Associations arising outside assigned workspaces are called *spontaneous associations*. Spontaneous associations are the primary metric of interest in this study. Since we are analyzing data from disCourse, in which participation is primarily driven by university courses, we conduct our analysis on a semester basis. Students are assigned to a class workspace at the beginning of the semester. Associations due to interactions between members within these workspaces cannot be considered the basis for bridging socio-technical capital; as such associations could be dictated by classroom requirements. Since sub-workspaces are sometimes created throughout the semester, co-membership is inherited from parent workspaces. Our analysis seeks out associations that take place either between two people who were not assigned to the same workspace in the first two weeks of the semester, or who were but the mediating artifact is situated outside of their mutual workspace. These associations indicate bridging socio-technical capital that would not have been obtained in a silo approach to online learning.

Sample

We analyzed data from four academic semesters (fall 2007, spring 2008, fall 2008, spring 2009) to search for spontaneous artifact-mediated associations between disCourse users. All users of disCourse and their artifacts were included in the analysis. Users include graduate and undergraduate students, faculty, and a small number of others associated with one of our five degree programs. Workspaces exist for courses, research projects, individual projects, degree program materials, and special interest topics.

Procedure

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Prometheus servers log events in a MySQL database. These log entries were transformed and filtered using operations similar to those of exploratory sequential data analysis (Sanderson & Fisher, 1994). For a given artifact type (discussion, resource, user profile, or wiki page), the analysis proceeded as follows. First, we selected all events in which any user accessed any instance of the given artifact type at any time. We further constrained these events to the time period in question (the semester being analyzed). Joins with other database tables determined the creator of the artifact and the workspace, if any, that the artifact belonged to. Further computation determined whether the accessing user belonged to that workspace or one of its parent workspaces, and if so, when the user joined that workspace. The accessing and originating users were considered as having an assigned association if they were both members of the workspace or a parent workspace containing the artifact in the first two weeks of the semester, and as having a spontaneous association otherwise. The frequency counts reported in the results section are counts of the number of accessor-artifact pairs in the resulting associogram (i.e., the dotted line in Figure 2). We report both total number of accessor-artifact pairs and the number of those that are due to spontaneous associations. In either case, the resulting set of accessor-artifact-originator triplets were visualized in associograms for our inspection. Finally, we manually examined the artifacts and profiles of users involved in about half the bridging events in order to characterize the apparent nature of the events (i.e., apply our judgment concerning what the users appeared to be doing).

Relation to prior work

The present paper improves on and extends a preliminary analysis reported in Suthers et al. (2009) as follows. First, the present analysis includes more recent usage data. Second, the prior analysis included false positives generated when sub-workspaces were created after the first two weeks of a semester, while the present analysis climbs the workspace containment hierarchy to check for co-membership in a parent workspace. Third, the present analysis provides quantitative summaries of the proportion of bridging to overall activity. Fourth, while the prior analysis used ad-hoc methods, the present analysis uses prototypes of tools based on an analytic framework we are developing (Suthers, Dwyer, Medina, & Vatrapu, 2010; Suthers & Rosen, 2009).

Results and discussion

The quantitative results are summarized in Table 1. The "SA" column shows counts for spontaneous associations, enabling a quantitative comparison of bridging activity (access to potential additional value provided by the open learning environment) mediated by each of the artifact types. The "Total" column includes both spontaneous and assigned associations, providing a measure of overall level of activity for the indicated artifact type. The ratio of the two, "%S/T", indicates what percentage of the total activity constitutes bridging activity. Values are shown for each semester, and the average across semesters on the right.

Table 1. Quantitative results of artifact-mediated associations

Artifact	Sem.	SA	Total	% S/T	Sem.	SA	Total	% S/T	Avg SA	Avg Total	Avg % S/T
Discussions	Fall 07	232	4884	4.8	Fall 08	218	2903	7.5	216	3411	6.3
	Spr 08	192	3406	5.6	Spr 09	221	2449	9.0			
Profiles	Fall 07	477	1103	43.2	Fall 08	288	924	31.2	305	877	34.8
	Spr 08	235	788	29.8	Spr 09	219	692	31.6			
Resources	Fall 07	48	139	34.5	Fall 08	45	273	16.5	54	168	32.1
	Spr 08	93	139	66.9	Spr 09	30	122	24.6			
Wiki Pages	Fall 07	115	8919	1.3	Fall 08	32	5723	0.6	63	6432	1.0
	Spr 08	93	5924	1.6	Spr 09	10	5163	0.2			

Comparing the semesters, relative magnitudes of activity are consistent across the semesters, but the overall levels drop off in the spring semester. This may be an artifact of variation in instructor practices across courses, or due to increased activity by new students exploring a novel environment for the first time in the fall. Ranking the artifact types by the total level of activity, wiki pages (average of 6432 accesses per semester) have the most activity, followed by discussions (3411), profile views (877), and resource access (168). This provides an indication of the importance, by frequency of access, of each artifact type to the online activity of students in

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this environment. But the ranking differs according to spontaneous association counts: Profiles (305) account for the most bridging events, followed by discussions (216), wiki pages (63), and resources (54). Those artifact types that receive the most activity have the lowest percentage of bridging events: the ranking by percentages is profiles (34.8%), resources (32.1%), discussions (6.3%) and wiki pages (1.0%). Examination of individual events and their artifacts shows that students are viewing class materials in classes that they are not enrolled in. Many of these spontaneous associations cross between the degree programs. We discuss each artifact type in further detail below.

Discussions and wiki pages

The majority of the activity of participants in this environment takes place in discussions and wikis: they are important resources for the work being done. This result can be understood in terms of how the properties of these media are appropriated in practice. Both media are *mutable:* normal use of a discussion and wiki page might involve posting or editing activities, respectively, in contrast to profiles and resources, which are modified infrequently and typically used primarily by reading. Students are often expected to participate in discussions, and the content of discussions changes over time, motivating repeated access. Wiki pages may be used for dissemination of information to students, in which case only the instructor is expected to edit them, but in this case students may access them regularly for information; and some students edit the wiki pages associated with their project and dissertation work.

Examining the percentage of activity that bridges across instrumental workspaces, we find that discussions and wiki pages have dramatically low percentages (6.3% and 1.0% respectively). This finding could be dismissed as merely due to these media's effectiveness in supporting task-oriented activity within the workspaces, the high total counts resulting in a large denominator, but from the perspective of bridging socio-technical capital it is clear that there is unrealized potential. The explanation is straightforward: discussions and especially wiki pages exist primarily within workspace contexts, so bridging events would take place only if a user enters a workspace he or she was not a member of. The exception is a small number of discussions that belong to either no workspace or to multiple workspaces. (One user with system level privileges had linked discussions to multiple workspaces in an effort to foster continuity of a seminar across semesters.) This finding indicates that the potential value of discussions and wiki pages for other users would be better realized if we figured out ways to make them visible and accessible outside of their workspace contexts.

Profiles and resources

Unlike discussions and wikis, *user profiles and resources* are more accessible outside of workspaces. When new resources are posted and made public, they are listed on a "new resources" list on the home page. There is also a resources page by which one may search for resources. Also, most artifacts have a user name associated that is linked to the user's profile, and one can also use the membership page to search for and view others' profiles. Therefore, even though the total number of accesses to these artifact types was lower, a greater percentage of associations mediated by these two kinds of artifacts bridged instrumental contexts. Some of the profile views are between persons who are in the same class; however a large portion of the profile views occurs outside of class workspaces. This activity suggests that disCourse users are utilizing profiles, and discovering users from groups that are external to their own. Many resources are not linked to any particular workspace and would not be seen in a user's regular daily navigation, and yet users are viewing these unlinked artifacts. This may be because the home page displays a list of recently added resources. Also, although the site-wide search facility searches all artifact types, profiles resources and discussions have their own dedicated tabs for browsing and searching.

Summary

Results show that there is appreciable bridging across classes and programs, but the types of artifacts studied play different roles in mediating socio-technical capital as measured by bridging or spontaneous associations. While there is much more activity within wikis and discussions, it appears as though little of that activity helps users expand beyond their silos. Meanwhile, an appreciable percentage of access to profiles and resources (about a third) are bridging events, but these artifacts support fewer associations, which limits their contribution to bridging socio-technical capital. Discussions and wikis encourage interaction between users that profiles and

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resources do not. Ideally, we would like to design media that combine the positive attributes of each to have high levels of unsolicited bridging activity.

Conclusions

The analysis reported in this paper examined the extent to which people who come to the online environment for instrumental objectives such as taking a course encounter persons or products of others from outside their course workspace. Various digital media available in an online learning environment—discussions, resources, user profiles, and wiki pages—were compared in terms of how they support these encounters. Addressing our first research question, the results indicate that users are finding value (as measured by their initiative in modifying and viewing digital artifacts) outside the workspace context that meets their instrumental objectives in using the environment (taking a class). Since the value derives from others and is mediated by digital artifacts outside of the class workspace context, we have evidence for *bridging socio-technical capital*. The implication for networked learning is that students can gain value from others if educational activities are conducted in digital environments that are embedded in a larger community space, rather than isolated from each other.

Yet, not all media are equal and there is room for improvement. Turning to our second research question, we found that in our current design bridging socio-technical capital is realized the most via discussions and resources, while the greatest potential in terms of percentage of bridging events lies in profiles and resources. To take advantage of these vectors for social capital, we should make profiles and resources visible wherever they are relevant. We should also examine what users are *doing* with the artifacts they encounter, and consider adding more options for activity (e.g., personal messaging) that further realize the potential for socio-technical capital.

It is not surprising that wiki pages did not bridge between class contexts, as these artifacts are created and encountered within workspaces, and one typically must have membership in the workspace to write to or edit these artifacts—e.g., be members of a class. Discussions are also most often encountered via workspaces, although not necessarily: one can enter discussions from the home page or from email notifications of discussion activity. The present results suggest that we need to find ways to make users aware of relevant discussions and especially wikis outside their primary workspaces, and increase opportunities for participation in these media.

A number of simplifications were deliberately made in this analysis to enable us to compute estimates of bridging socio-technical capital from log files. Limitations of the analysis point to several directions for future work. Associations can be measured at multiple granularities. For this initial analysis, we have chosen to count each person's access to a given artifact just once. A more sensitive measure might be obtained by counting each person's access an the artifact every time it has been modified by someone since the previous access, as there may be new value in the modified artifact. We could also count all access events even if the artifact has not changed under the reasoning that a user returns to artifacts that offer more value. Another direction for future work is to "ground truth" the log file analysis. Interviews could be conducted to obtain participants' retrospective impressions of what they find valuable in this environment and to check our interpretations against these impressions. Further work can identify the kinds of associations that are taking place via the technological environment that facilitate generation and spread of ideas, lead to face-to-face relationships, or form the basis for the development of students' professional identities.

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