Infrastructuring New Media for Education

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ABSTRACT

Analyses of the implementation and use of new participative media have traditionally focused on one of three main perspectives: the development of the technology, its activity or task-driven use in organisational or distributed settings, or the social arrangements that facilitate such distributed work in general or the social production of information in particular. Drawing on an infrastructural approach (Lievrouw & Livingstone, 2006; Star & Ruhleder, 1996) this paper argues for a more integrative perspective that pays equal attention to each perspective during the implementation and use of new media. An infrastructural analysis of two cases of the implementation of new media in educational settings is used to illustrate the value of the approach. Findings from the analysis highlight the issues and problems of infrastructuring for education at different orders of complexity e.g. resource constraints, the traversal and bridging of multiple contexts, and political controversies. Implications for infrastructural work and for research and practice in supporting the implementation and use of new media in educational settings are addressed.

BACKGROUND AND PURPOSE

Educational settings have become a prime location for the implementation and use of virtual learning environments and new media tools that aim to increase learners' participation in the educational process. Their implementation has enabled has enabled more participative forms of information behaviour and the study of people's direct and indirect collaboration in the discovery of information and its subsequent sharing, discussion, and application. Research has tended to study these participative forms of information behavior from three main perspectives: (a) the shared activities and practices that motivate the seeking, search, evaluation and use of information on a collaborative basis (b) the design and use of technologies to support collaborative information seeking and retrieval; and (c) the social arrangements and organisational forms that underpin distributed collaboration in general and the social production of information in particular (e.g. Hinds and Kiesler, 2002; Richter, Bray & Dutton, 2010). Drawing on infrastructure theory (Star & Bowker, 2002; Lievrouw & Livingstone, 2006, 2002) this paper argues however that the implementation of new participative media is shaped by a mutually constitutive interaction between the artefacts, practices and social or organizational arrangements that underpin its use. Moreover that effective organizational and educational design for the implementation

and use of virtual learning environments and new media tools in educational settings requires infrastructural work that pays equal attention to each perspective.

The organization of the paper is as follows. First the paper defines and explains the concept of infrastructure that is being used. Second a literature review is presented of studies that have investigated participative information behavior from one of three main perspectives. Both general studies as well as studies that have been conducted more specifically within the educational domain are reviewed. We also show how prior work on information behavior might benefit from being viewed from an infrastructural perspective. Third, an infrastructural analysis of two complementary cases is presented that illustrate the issues attendant on the implementation and take-up of new media in educational settings. The paper concludes by addressing the research and practical implications of doing infrastructural work in educational settings.

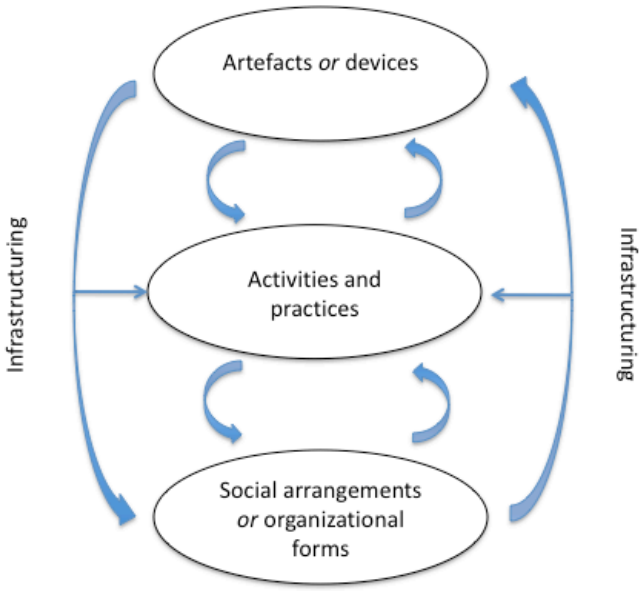
THE CONCEPT OF INFRASTRUCTURE

The 1990s and 2000s marked a decisive period in the history of media. Prior to this, audiences and users were largely the passive recipients of one-way communications and standardised content. Media convergence and the adoption of the Internet and the World Wide Web as a major communications and distribution platform has enabled a greater degree of interactivity and the active participation of audiences in constructing and shaping its use:

> "… by new media we mean information and communication technologies and their associated social contexts, incorporating: the artefacts or devices that enable and extend our abilities to communicate; the communication activities or practices we engage in to develop and use these devices; and the social arrangements or organizations that form around the devices and practices" (Lievrouw and Livingstone, 2002: 7).

Such a definition points not only to new mediated experiences but also to how new media shapes and is shaped by the contexts of its use. And it is the dimensions of these contexts and the relations between that should also occupy our interest (see Fig.1).

Fig.1.Infrastructuring Artefacts, Activities, and Social Arrangements



In a subsequent consideration of this definition the authors also provide these comments:

> …we do not specify a priori any set relationship among the three component processes of infrastructure. Where the mass communication tradition has spent decades struggling with, and, more recently, unpicking the linear relationship along production, text, and audience (i.e., production makes texts which have effects or impacts on audiences, consistent with the sender-message-receiver model of communication), in new media research no such linear assumption is necessary. This is why we emphasize social shaping and social consequences together…as an ensemble: it is precisely the dynamic links and interdependencies among artefacts, practices, and social arrangements that should guide our analytic focus (Lievrouw and Livingstone, 2006:3)

It is such an understanding of infrastructure that we use here to inform our analysis of the implementation and use of new media in educational settings. Rather than defining infrastructure as it is commonly understood, i.e. as a type of engineered object, the notion of infrastructure we deploy here is a relational and contextual one. It is an idea of infrastructure as a meta-communicative context that stretches across the levels of artefacts, activities and practices, and social and organizational arrangements. Before illustrating this infrastructural approach within an educational context, studies that have approached the implementation and use of new participative media from each of these three distinct perspectives are considered first.

LITERATURE REVIEW

Collaborative Information Artefacts or Devices

The first infrastructural context we consider is "the artefacts or devices that enable or extend our ability to communicate" (Lievrouw & Livingstone, 2006). Principally this means the Internet, both as a source of information and as a platform for communication, work and learning. Additionally this level of context includes (i) the specific artefacts that are jointly produced via this platform e.g. Wikipedia, shared digital archives and repositories, open source software (Reagle, 2010; Benkler, 2006) (ii) the technological devices that enable end-users to jointly produce these artefacts (e.g. blogs, wikis, virtual environments etc) or to participate in the joint discovery, organization, sharing, use and re-use of information more generally (e.g. collaborative information retrieval and search tools, recommenders, social bookmarking and tagging tools, social network sites etc). Examples of relevant devices include the early *Ariadne* system (Twidale & Nichols, 1998a, 1998b; Crabtree et al. 2000) that drew on understandings of formal and informal collaboration in physical libraries to develop an interface that provided visualizations that enable the search process to be shared among the participants; and more latterly the *SearchTogether* system (Morris & Horvitz, 2007) that enables the sharing of search queries and results Specifically within an educational setting Shapira et al. (2001) describe the design of a collaborative information-finding system ANTworld where the effects of motivation on students' provision of evaluations to a shared educational resource are studied; while Scown (2010) describes the development of a digital video repository that is contributed to and re-used by successive cohorts of students. Such studies provide the needed perspective on the design and evaluation of the technological possibilities of collaborative information artefacts; they tend to focus less though on a systematic investigation of the activities and/or practices, and the organizational and/or social arrangements that sustain such artefacts in use. Therefore we now turn to consider examples of the activities and practices people engage in to develop and use these artefacts.

Collaborative Information Activities and Practices

Collaborative information activities and practices are often observed as occurring within the context of purposeful intentional work where a division of labor occurs or a distribution of expertise is required. Reddy, Jansen, and Spence (2010) describe a body of work in which collaborative information behavior (CIB) occurs in medical settings where information flow breakdowns occur and CIB is triggered by the complexity of an information need or a lack of immediately accessible information, a lack of domain expertise or fragmented information resources. Such situations have been observed to occur in the work of patient care teams in surgical intensive care units and that of emergency departments. In such contexts electronic patient records and other web-based systems often act as a starting point for further collaborative diagnosis and discussion. The embeddedness of collaborative information seeking and retrieval and information sharing in broader work activities has been observed from some of the earliest studies (e.g. Hansen and Jarvelin, 2005). A more recent study (Ikeya, Awamura, and Sakai, 2010) also highlights the differences in granularity between information sharing and work practices, and also highlights the changes that

may be needed at the level of work practices in order to accommodate differences at the level of information sharing.

Educational settings have also been studied as a context in which collaborative information activities and practices take place. These often take the form of group work or learning tasks that motivate learners to collaboratively seek, search and use information from electronic sources. Hyldegård (2009; 2006) collected data on the cognitive and affective experiences, and physical actions, of two groups of information science students as they sought, retrieved and used information over the course of seven weeks in support of a project assignment. The aim of the study was to explore group members' information behavior and to see whether the intra-group member's information search process differed from that described in the ISP model, and whether such differences were associated with group task and social factors. Information search processes in a group have more difficulties and were significantly less focused in groups where members were not familiar with each other. Affective factors, in contrast, were sensitized to uncertainty about the information search process and external factors related to the complexity introduced by making search collaborative. In these contexts the term collaborative information behavior is used as a term to classify and organize a sequence of discrete information actions into a chain of interdependent tasks e.g. identifying and negotiating a shared information need, information seeking, retrieving and evaluating, discussing, using and re-using information (Foster, 2010a, 2010c; Talja and Hansen, 2010). One of the key mediating mechanisms through which work and learning gets done is language. Drawing on a language-based model of learning Foster (2009; 2010) provides an analysis of learners' discussions as they interpret and use the information once it has been sought and retrieved from electronic sources as part of a group learning activity; and the functions and forms of collaborative talk that are educationally valuable are identified. The use of social media in education is becoming more widely diffused and studied. For example Deng and Yuen (2011) develop an educational framework for the use of blogs in teacher education that incorporates the activities of blog-reading, self-expression, self-reflection, social interaction, and reflective dialogue. Using Facebook as an example Mazman & Usluel (2010:444) refer to the need to also provide "informal learning contexts by integrating emerging social networks into existing learning practices". Some of the potentially more detrimental effects of social media use in education are however highlighted by Junco and Cotton's (2011) study which explores the sometimes deleterious effects of instant messaging on students' perceptions of their educational attainment.

Wikipedia and Facebook are currently two of the most prominent examples of collaborative information systems. In a technologically deterministic analysis, the artefact production and storage "system" is viewed as infrastructure. Infrastructure is in practice more than the technology and an overwhelming corpus of research on the uptake and use of such systems shows substantial variation in the practices and organizational structures that emerge around them (Sawyer, 2010). Some of these variations include centralized vs. decentralized control of the system; and whether the system operates in a public or private environment.. Wikipedia is a centrally managed collaborative information behavior site. Its purpose is reference information sharing like that found in a traditional encyclopaedia. Facebook, in contrast, is highly decentralized around the ego networks of account holders and exists to support social interaction. Information is shared on Facebook, but that is not the sites primary

purpose. Both are highly distributed, technologically mediated places where collaboration occurs, and artefacts are created. The two sites however have different, contrasting traits relating to collaborative information behavior. While Wikipedia is a collaborative information reference environment that is widely studied but under theorized from the perspective of information science; Facebook can be considered to be a new type of information grounds (Fisher & Naumer, 2006). Information plays a different role in the social construction of each environment. Information grounds theory helps to explain the differences between these two centralized and decentralized environments. There is a tendency to treat the virtual places where information artefacts are created and maintained as "various similar electronic buckets". Artefact production, however, varies significantly from bucket to bucket. Information grounds theory brings these differences into focus. There are seven propositions that constitute information grounds as a notion of a physical space or "third space" where information is shared (Fisher & Naumer, 2006).

1. Information grounds can be anywhere, at any time. They merely require people to be present.
2. The primary purpose of gathering is something other than information exchange
3. Most information grounds participants play expected and important roles in information flow
4. Social interaction is the main purpose of information grounds. Information flow is secondary.
5. Information sharing is formal, informal and multi-directional
6. Benefits & uses of information include the physical, social, affective and cognitive dimensions.
7. Perspectives of participants and physical characteristics of the space lead to many subcontexts that exist within a grand context

Table 1 compares the extent to which Facebook and Wikipedia may be viewed as socio-technical information grounds. We see that Facebook satisfies all of the propositions for information grounds while Wikipedia, a more deliberately designed information resource, does not. Collaborative information behavior in social and participatory media takes a different shape, depending on the social (or non-social) structure, the practices that develop and the technology in use. The configuration of this technology, in turn, influences the sorts of artefacts produced.

Table 1 - Facebook & Wikipedia as Information Grounds

Information Grounds Proposition	*Facebook*	*Wikipedia*
1	(Yes) Users of Facebook are aware of others that are synchronously present through chat awareness, and others who are asynchronously present through posting and social navigation	(Partial) The presence of others is not universal across all Wikipedia content. Certain roles are visible within the environment.
2	(Yes) Social awareness and connection are the primary purposes; information is exchanged incidentally.	(No) Information is the primary purpose of Wikipedia
3	(Yes) Gurzick (2010) shows that Facebook participants play different roles	(Yes) Roles are clear in Wikipedia.

	in the dissemination of information, and Facebook provides multiple avenues for linking and connecting information.	
4	(Yes) Social Interaction is the main purpose of Facebook	(No) Information is the main purpose of Wikipedia.
5	(Yes) There are formal technical affordances as well as informal ones for sharing information on Facebook. There is also the widely used ability to link other information in to Facebook.	(No) Information sharing is highly formalized
6	(Yes, in theory) We are not aware of empirical work to substantiate the claim that physical dimensions are incorporated into Facebook. Features like Places imply at least a reference to a physical place.	(Yes, In theory) We are not aware of empirical verification, but the information contained in Wikipedia is not restricted to particular topic areas.
7	(Yes) For example, Facebook friends, Groups and links are subcontexts within the larger Facebook grand context.	(Yes) Wikipedia has topical and linquistic subcontexts that exist within a grand Wikipedia context.

Decentralization produces a socio-technical information grounds in Facebook, where friend lists are predominantly composed of friends and acquaintances from the physical world (Lampe, Ellison & Steinfield, 2008), which, combined with its lack of bounding to one specific component of an individual's physical world, renders it a genuine "virtual third place" of the type Fisher & Naumer describe.

Wikipedia, in contrast, is a more complex socio-technical information space that does not, as Table 1 shows, approximate an information grounds. Wikipedia relies on an open source technology, Mediawiki, which is reused by organizations who wish to maintain proprietary wikis. Mediawiki constructed artefacts are more well formed & structured than Facebook posts because it includes a special form of text called "creole" for formatting articles. This text makes the act of producing information in a uniform manner less onerous than with a traditional website. Collaborative information behavior on Wikipedia is enacted through a robust, stable, consistent and relatively simple to use technology. Wikipedia is an elaborate, highly adaptable bureaucratically managed system. The effects of cenralized management on consistency of production are clear. Wikipedian culture demonstrates practices for preventing vandalism (Priedhorsky et al., 2007), rewarding good behavior (Kriplean, Beschastnikh, & McDonald, 2008) and managing organizational roles (Kittur, Suh, Pendleton, & Chi, 2007; Kriplean et al., 2008). Wikipedia is an example of how a large, community effort, guided with a formal, almost bureaucratic infrastructure, can produce a high quality online information product (Kittur, Chi, Pendelton, Suh, & Mytkowicz, 2007; Kittur & Kraut, 2008). Facebook, in contrast, produces artefacts more reminiscent of newspapers strewn about a coffee shop on Sunday morning. It is an information grounds, but is not a consistent producer of reusable information. Studies of Wikipedia have also been conducted within an educational context (e.g. Forte & Bruckman, 2006). Traditional modes of education focus on the evaluation of completed artefacts by an expert-teacher, while the use of Wikipedia in the classroom enables students to collaborate more on works in progress and expose earlier, more intermediate drafts to teachers for feedback (Forte & Bruckman, 2006). In educational applications, then, we see that the infrastructure surrounding artefact production is potentially shifted by the introduction of wikis, and the potential new practices they enable.

This review of collaborative information activities and practices highlights the activities and practices that users engage in to develop and use collaborative information artefacts and devices. As the review illustrates some of these activities and practices have developed within the context of existing work and learning contexts. At the same time the review highlights how networked technologies give rise to new work and learning opportunities. In tandem with this new social arrangements and organizational forms are emerging to accommodate some of these more networked practices. The final level of our literature review identifies studies that are beginning to address some of these challenges at this level of scale.

Social Arrangements and Organizational Forms

Many of the activities and practices that draw on the artefacts and devices occur in an organizational context. Research into collaborative information activities and practices is often framed within the work of formal organizations, while recent studies of widespread collaboration around information also focuses on websites and web tools. There is a gulf between the organizational research and web collaboration research on the use of devices in support of collaboration or the development of collaborative information artefacts. An organizationally-focused approach is illustrated for example by Reddy & Dourish (2002) examine the temporal rhythms of CIB in a hospital setting, and Spence & Reddy (2008) examine the collaborative information behaviors in a traditional ER. CIB is necessarily a social activity, of course, but there is a great deal of research on information behavior more generally, and as Reddy & Jansen (2008) point out, most of that research is conducted at the individual unit of analysis, which they frame as individual information behavior (IIB). The social dimension of information behavior is alluded to in earlier work using ambiguous references to "collectives" (Dervin, 1992) and descriptions of information behavior "among" others (Brown, 1991). Reddy & Jansen distinguish between the identification of the collaborative aspects of information behavior, and the active pursuit of CIB-centered empirical research. CIB is not a group situated form of IIB; it is a phenomena warranting focused research. A small number of studies focus on CIB and the social unit of analysis (Fidel, 2004; Foster, 2009; Goggins & Erdelez, 2010; Poltrock et al, 2003; Reddy & Jansen, 2008; Twidale, 2005), but transitions between individual and group information behavior in all contexts remain less well understood. Reddy & Jansen (2008) explicate a model for understanding the triggers for CIB instead of individual information behavior. In Reddy & Jansen's study of collaboration in two medical environments, social interactions still occur with individual information behavior, but they take the form of question-answer exchanges. Medical environments share characteristics with online learning, including the complex, dynamic and time critical nature of the activities.

Networked and technology focused studies of collaborative information activities and practices sit in contrast to those studies that pursue a more organizationally situated phenomena. Hendrickson (2010) describes the development of a virtual newsroom mediated by instant messaging; along with some of the implications of how existing organizational forms of news gathering are reinforced while also creating possibilities for new practices. While Noel and Lemire (2010) identify some of the challenges of preparing and facilitating the analysis of research data on a distributed basis. As an example of a more networked form of research Richter, Bray and Dutton (2010)

describe an example of how the Internet enables new forms of networked organization in the film community. Another example of networked organizations is citizen science initiatives that lead to new participatory practices in the domain of science (Wiggins & Crowston, 2010).

INFRASTRUCTURING FOR NEW MEDIA IN EDUCATION

Drawing on Star & Ruhleder's (1996) infrastructural analysis of the development of an electronic worm community and associated Worm Community System (WCS) we characterize infrastructure as a "context for both communication and learning within the web of computing" (Star & Ruhleder, 2006: xx). Therefore in keeping with Star & Ruhleder's characterization our notion of infrastructure does not define a thing but a relation between things. For example, instead of referring to a technical substrate that underpins the running of software and the transportation of data, the idea of infrastructure points to the changing and dynamic communications and relations between practices, artefacts, and social/organizational arrangements. In characterizing this communicative context Star & Ruhleder distinguish three levels or orders of issues that occurred during the development of the WCS; issues that became visible in the communication between the users and the developers of the system. The notion of these issue levels is useful for analysis of existing infrastructure because communication about infrastructure is most likely to occur when issues surrounding the infrastructure surface. Although we do not claim that the mapping is exact, it is analytically useful to consider each of these levels or orders to be roughly coextensive with Lievrouw & Livingstone's tripartite distinction between artefacts, practices, and social/organizational arrangements.

First order issues are perhaps the simplest to address and concern matters of resource allocation including information e.g. Does the virtual learning environment have an e-mail account? Have my course files been transferred from last year? Do I need to download a plug-in in order to access the virtual learning environment or can I access it from anywhere? Second order issues are more complex and may involve two or more contexts and/or unforeseen contextual effects. For example, if I use the university's virtual learning environment to teach my classes can students from other universities also access the learning environment? If I teach online does this mean the arrangements for contact hours will be different? Third order issues are the most complex to resolve and refer to issues of value or of politics during infrastructure development; for example, what should the pedagogy be for online learning? Do the values that this institution upholds support the implementation of online learning?

Issues are identifiable as communication about infrastructure. Star & Ruhleder define infrastructure as a communicative context for learning, and their schema focuses on analysis of statements within that communicative context; in their case the WCS. Each discrete communication episode may reference a range of contexts, rather than artefacts, practices, social/organizational arrangements per se. Therefore, this communication is viewed as constitutive of the objects rather than a simple, transparent window on objects. Second, these contexts are discontinuous. Gaps between issues at different levels of systems within organizations (e.g. level 1 and level 3) leading to paradoxes for the organization concerned. For example, in the two cases that follow, learning about educational groupware (level 1 issue) within the

context of an institution that does not, according to the values inherent in its mission, necessarily support the practice of online learning (level 3 issue).

Next, we present two cases that illustrate Star & Ruhleder's three levels of infrastructural issues in the implementation of technology to support learning in a university setting. The cases are designed to be complementary in several ways: audience: university staff vs. students; perspective: top-down vs. bottom-up; and time (the beginnings of research into networked learning vs. current developments; organization and network). Taken together we believe that a generalizable account of the main infrastructural issues can be extrapolated. The first case examines the broad organizational issues associated with enhancing classroom learning with technology. The second case examines graduate level classes taking up and using organizationally provided and free and open source technology to support completely online learning groups. These cases provide important contrasts across two dimensions. First, the organizational perspective can be considered a top town analysis of issues related to changes in infrastructure, while the course perspective is analyzed from the bottom up practices of system users. Second, one case relates to the adoption of technology that is part of a physical classroom, while the other case examines infrastructure as constituting the classroom entirely. It is the task of infrastructuring to attempt to bridge some of the gaps between different issues at different levels. Star & Bowker (2006) develop the argument further in addressing the question and implications of how to infrastructure.

The respective case analyses initially draw on Star & Ruhleder's three levels or orders of issues as a schema for categorizing the issues that arise within the different contexts of infrastructure. Each case also identifies some of the opportunities for addressing infrastructural transcontextual syndrome within their respective communicative systems. The case section concludes with a discussion section considers some of the generic implications of considering infrastructuring as a continuum that incorporates face-to-face and completely online contexts.

Campus-Based Case

Case 1 re-visits and re-analyses the work of a teaching and learning development project (Foster, 2002; 2000) at the beginnings of research and development activity in this area. The aim of the project was to work alongside university academics to design, implement and evaluate the introduction of computer-based collaborative group work and learning strategies into their practice. The multi-stranded nature of this project led to the identification of a range of issues that could not be resolved at any one level of communication or learning. Hence the case provides a unique perspective on understanding the infrastructural issues that occur during the implementation of virtual learning environments within a particular organizational context.

CASE 1

The CBCGW project aimed at developing, implementing and evaluating the introduction of computer-based collaborative group work strategies within a university environment. The work, and different strands, of this project illustrate well the analytical distinction made by Lievrouw and Livingstone between artefacts, practices, and social/organizational arrangements, and the infrastructural issues that emerged from attempting to implement CBCGW within a particular organizational

context. The strands of the project were: a study of institutional readiness for networked learning; a case study evaluation of generic online teaching and learning strategies, the implementation of a professional development environment along with a national professional development centre, and an evaluation of educational groupware.

The following analysis identifies the infrastructural issues that arose during project-user communication. In particular it analyses statements that arose from interviews conducted by the project team with members of the university e.g. academics, managers, support staff hence the issues are based on statements that arose within project-user communication. Users were grouped into managers, academics, and support staff. Each level or order of issue identified emerges within the general theme of institutional readiness for networked learning.

First Order Issues

Knowledge gaps

At one level members of the university community wanted to know more about a number of issues relevant to the design, implementation and use of networked learning. This included a desire to understand more about what networked learning is, any educational benefits, the associated costs, and the technical and organizational impact on the university.

Technical infrastructure

One of the barriers to implementing networked learning is the requisite technical infrastructure. As one manager commented:

> …we are developing strategy but unless somebody sorts out the underlying structure and infrastructure we are not going to be able to deliver it […] it is not putting the strategy in place, it's delivering it.

Campus-wide learning about networked learning

While a lack of resources in support of practice were identified as one set of issues; an interviewee also commented on a gap between research into networked learning and existing channels for disseminating this research at an institutional level of scale:

> I think my feeling at the moment is that there is still a kind of dual thing going on, that there are researchers doing things and generating kind of information and knowledge and there's sort of a channel for quality making and reflecting on practice […] and I'm not sure whether there is a kind of a link across.

Addressing First Order Issues

Resources available to members of the university community for learning more about networked learning included participating in informal networks of expertise within the academic community, accessing research information, and attending staff development courses. For its part the CBCGW project attempted to bridge some of the knowledge gaps through the provision of a fortnightly Alert Service that drew university members' attention to relevant research and current developments; and opportunities to either develop a networked learning module with a member of the

CBCGW team within their own curriculum, or participate in a professional development course designed by the CBCGW team. While these resources act as an aid in the support of academic practice there was also a need as other interviewees noted, to address issues arising within some of the other contexts relevant to innovation in networked learning e.g. IT support and university administration. Clearly the provision of a shared interoperable technical infrastructure is central to its implementation; while greater consideration of the connection between research information and academic practice as part of administrative design was also deemed as being potentially beneficial.

Second Order Issues

As mentioned previously second order issues are more complex and may involve either unforeseen contextual effects and/or the interaction between two or more contexts.

Time as a resource

An unforeseen contextual effect highlighted by a member of the academic community was the issue of time:

> If you are going to be responding to students…through the web…I'm not sure that our notion of what is teaching is kind of geared up to that because it is pretty much geared around the idea of you go into the lecture or class and a certain amount of time set aside for tutoring also but this is a much more fluid and open ended time commitment and…I am not aware of much discussion about that.

In contrast to face-to-face teaching innovations in online learning can have a quite different effect on academic practices; and this interviewee called for wider consideration of the nature of the embedding of networked learning within existing academic practice.

Interaction between management, academic, and IT contexts.

While both grassroots academic practice and the development of technical infrastructure are key ingredients in the implementation of networked learning it is also clear that while these are necessary they are not sufficient elements in themselves to accomplish organizational transformation. In this respect the support of management is also necessary; and evidence from the interviews pointed to how academic and support staff would also look to management and administration to steer developments in this regard. As one academic interviewee put it:

> I can see some readiness in the structures that are there […] but I still feel that it is a little bit devolved and the responsibility is with the departments and with course teams and I don't have the sense that there is a sort of institutional push to do things.

While a member of the university's support staff commented:

> Much as I agree with things being done in a bottom up way there is a very big role for leadership from the top as well…both management but also the top

> academic level […] without support from the top we are not going to go anywhere.

External regimes of accountability.
Finally the interaction between the university as an organization and external regulatory bodies was also perceived as being relevant to innovations in networked learning. The university does well in teaching quality assessments and in the UK research assessment exercises. Paradoxically the organisation's high performance within the context of existing regimes of accountability (Wenger, 1998) can act as a brake on internal innovation.

Addressing Second Order Issues
Second order issues cannot simply be resolved through a reallocation of existing resources or the provision of new ones. Their resolution requires either a challenging of the assumptive contexts (e.g. academic practices) that impinge on the context under consideration (e.g. networked learning) or greater coordination across the relevant contexts (e.g. academic, management, support) – either practically (e.g. teaching and learning support for networked learning) or conceptually (e.g. an organizing vision).

Third Order Issues
Pedagogy for online education.
Although knowledge gaps and some differences in terminology were identified; more intractable differences existed as to the appropriate pedagogy for online education. Typically this revolved around similar issues that are encountered in face-to-face teaching i.e. information giving and exposition vs. discussion and negotiation of meaning.

Multiple meanings of networked learning.
Issues relating to the practice and meaning of networked learning in the classroom aside; negotiating the meaning of networked learning across the different groups of stakeholders e.g. academics, managers, support staff and for the institution as a whole more broadly was a live issue. How fixed and how negotiable these meanings are is pertinent here.
Institutional mission and organizational values
Perhaps most intractable of all is the constraining influence of an organization's mission and values on its culture and practices; and that any realistic internal organizational transformation requires recognition of and alignment with these values. As one manager commented:

> …it would be consistent with this university's mission to say we are not actually interested in encouraging distance learning, we are not particularly interested in encouraging networked learning as part of our strategic mission but merely to support the activities we would otherwise engage in.

Addressing Third Order Issues
As Star & Ruhleder point out third order issues are the most intractable and contested, involving issues of values, politics, and entrenched positions. In this respect it was useful to think and work through each individual perspectives within the context of organizational design for learning:

> …in the end it is in the opportunities for negotiating meaning creatively that the learning of an organization resides […] this focus on the negotiation of meaning is a focus on the potential for new meanings embedded in an organization. It is a focus not on knowledge as an accumulated commodity – as the ability to repeat the past – but on learning as a social system productive of new meanings (Wenger, 1998).

And negotiating meaning creatively will involve engagement, imagination and alignment on the part of members of the organization.

Case 2: The Completely Online Case

The first case examined practices of an institution, and the organizational units and practices of that institution by interviewing stakeholders about the issues and challenges that were arising during the implementation of an infrastructure. The second case complements the first in two ways. First, we examine a completely online context in case 2, while case 1 was focused on technology support for largely campus-based education. Second, the data in the second case is focused on the learning practices at the classroom, small group and individual learner units of analysis. Analytically, the second case is pursued at a finer grain of analysis, go as far down as individual learner interactions. By comparison, the analysis in the first case is more coarsely grained. Together, these cases represent a comprehensive survey of the infrastructural issues found in university application of technology to learning.

The second author studied the effects of context awareness tools on completely online graduate level courses at three major US Universities for five years. Completely online courses, like free and open source projects and Wikipedia editing occur without people ever meeting face to face. In the case of completely online courses, this is more absolute than it is with free and open source projects. Unlike large scale Internet facilitated projects, completely online graduate level courses have a managed structure with a significant time component and are contained within a clear organizational context. The courses studied incorporate a significant component of small group work, so in this respect, such courses are similar to organizationally situated work groups.

Completely online courses rely on technical infrastructure and pedagogical infrastructure (Goggins & Erdelez, 2010; Goggins, Laffey & Gallagher, 2011). As in the case of Star & Ruhleder's study, we find there is a tension between sanctioned, organizationally sponsored tools and more lightweight, publicly available tools. The organizationally sponsored tool studied here is the open source course management system, Sakai, with Context Aware Notification Services provided by CANS.

With the rest of this section, we briefly review the aspects of infrastructure in a completely online course, and then describe how the levels of infrastructure and the corresponding issues associated with those levels are enacted in a completely online course. We conclude this section with a discussion of the implications for collaborative information behaviour more broadly.

First Order Issues

Internet Connection Speeds in Rural Areas

Issues likely to arise at level one – information, knowledge of tools and basic access to systems – are manifest in completely online group work. First, some participants in rural areas continue to rely on dial up connections. Their mostly urban, high bandwidth connected peers are able to remain online for long periods of time, while paying only partial attention to the course. These differences in basic access to the course management system influence the extent to which members feel co-present and limit opportunities for rural members to spontaneously collaborate around information. At level one, infrastructure becomes partially visible in this way. This example from a course discussion board is representative of the types of issues that emerge around low speed access.

> Member 1: Sorry I was MIA last night. No dial-up internet access. I am looking for a good solution. Thank you for posting.
>
> Member 2: That's no fun! I occasionally have problems here too...only when my boys won't get off World of Warcraft and the other boys are downloading stuff! :)"

Member Adoption of Technical Infrastructure

Completely online course participants rely on local infrastructure in their homes for access and participation. When things go wrong, the participant can be completely disconnected from their online world. A typical example of how this becomes visible in an online course is a discussion board post:

> I am still having computer issues at home, but the tech guys here at the college are going to fix it for me, so I am trying to get as much work done on "borrowed" time at work and on my son's computer, which he just loves...:) I guess I could just ground him from the computer, and then there wouldn't be a problem any more :)

Task Coordination Across Technologies

Members of completely online courses experience coordination difficulties across the disparate technologies they use. The work of the group is defined as one deliverable, but members must work together to build a work plan in each case. For example, from the second author's field notes:

> There are a number of instances across multiple groups where people paste parts of an assignment into another tool so that it is readily available for negotiation, observation and coordination. This is visible in the chat dialogue between Celeste and Jacob in Module 4, and also in Terry's coordination work using discussion boards across the life of Group 8."

The tasks of the module are organized to facilitate student learning, and a natural progression of activity from section to section. This is not a work plan, but a pedagogical instrument. In order to execute the work as a group without getting together, the tasks must be identified and unpacked into discrete activities for which members are responsible in each group. Then, as the module progresses, members must keep track of deadlines and assignments so they are able to coordinate. Sometimes this is done through email, a wiki with a list of deadlines and occasionally a discussion board post that members refer back to.

In this case, we see how participants in the group address a key piece of limited information; and close the identified gap.

Addressing First Order Issues

In the completely online case, resource issues are addressed at the participant, group and course levels instead of the institutional levels described in the first case. In this context resources to support online learning are invented by instructors, participants and groups. For example, participants invent ways to coordinate tasks when the information is buried in the syllabus. Students are also able to, in some cases, seek resources outside of the university context from friends and co-workers when they encounter issues with local technology infrastructure. Other personal technology issues are not addressed directly, as in the case of rural participants who only have access to a dial up internet connection. These participants face infrastructural limitations that require compromise and change in their individual practices.

Second Order Issues

Establishing Group Practices With Diverse Social and Technical Infrastructure

Unlike organizational contexts, there are no well defined departments or structures in completely online groups. Participants actively integrate local, personal contexts that include information technology infrastructure, social situation and schedule into the context of a collaborative group. Some members rely on dial up, others work nights or do not have regular access to internet connections when at work. The course management system is the one, shared technology component, around which group practices begin to develop. Adopting the basic course management system requires members of the course to manage the transition of task work enumerated in a syllabus into a structure that both members and groups are able to keep track of. There are wikis, discussion boards and external tools available for this. Frequent and routine communication between members is one important practice that comes up in discussions with participants:

> … that means you're supposed to log into the discussion board once a day and you know check messages and post a reply then that is, that .. is your commitment to the team .., and you should be doing that, and obviously if you're not doing that then you're not working together as a team, and that's going to complicate things.

Leading group activities is a function that often rotates, so that members end up sharing the coordination work across the 16 week duration of the course:

> One person may have dominated a little more than the other but over all that didn't continue on to the next module. I probably dominated a little more in the cuta part but Susan picked us up on the other. I: So you kind of exchanged the role of the lead person? S: Yes, exactly.

Group practices center on the course management system and roles that members take on in the groups; and each of these choices are different in each group, even though they share the same technologies and tasks. Completely online groups, in this sense, construct their own infrastructure (Goggins, Laffey & Gallagher, 2011).

Time Zone and Work Setting Challenges

The difficulties of managing work across time zones are well documented, though have a different dimension in completely online groups. This difference arises out of the fact that members in other countries are not as connected to the internet as distributed work teams, who are nearly always contained within some organizational context that has developed the necessary infrastructure and knowledge of decoupled work, which is required for effective distributed work (Olson & Olson, 2000). These time zone challenges can exacerbate existing problems in groups:

> "I am struggling with that part with teamwork because my team mates they are for example, when I was in china because my starting time was very limited so I just hoped I can get a minimum requirement of that course. IT doesn't mean I am don't want to start any more, just the time schedule. My team mates have to know any problems about their working schedule so they hope our group work, our final work, can be as fast as we can so that is really inconvenienced me."

Note, however, that the issue is not purely an issue of time zone. It is time zone, combined with local work and technology context of each group member, which makes this issue particularly difficult.

Open & Public Collaboration Tools: The New Normal

Free and open source tools like Google Docs, Wikipedia, email and others have a similar effect to that observed by Star & Ruhleder (1996). The difference in the completely online case, fifteen years after the original Star & Ruhleder study, is that the novelty of their contrast between organizationally sponsored systems and lighter weight tools has worn off. It is replaced by a dominance of free, public tools for facilitating technologically mediated collaborations. Instead of understanding the resistance to organizationally sponsored tools, we must now consider how the use of such tools is ubiquitous, and subsequently integrated into online learning delivery.

Being in contact only through technology drives groups to adopt easy to use tools they are already familiar with; and creates resistance for often complex online course management systems. Just like Star & Ruhleder found, users will resist such complex systems in favor of simpler, more efficient ones. There are now hundreds of such systems in a socio-technical cacophony on the internet. For instructors, the challenge becomes ensuring knowledge of how such tools are applied to complete work in their classes. The extent of small group innovation that occurs fluidly and frequently in an online course, creating such learning challenges, is exemplified by this observation from a student in our study:

> "Am actually doing well in this group, I wasn't sure if this would be the case since a couple of the members tend to be chatty on the dbs. But we are negotiating an equilibrium. We haven't perfected it but are working well together. We are going to try google docs next module to see if we like it better than wikispace. We are starting to chat on Skype-my suggestion. We are breaking tasks down and creating timelines for comments, writing, and editing alternating the person responsible for the fun of posting final versions of our work."

In the completely online courses we study, small groups construct their own infrastructures of practice and technology using publicly available tools. Students today, even in completely online courses, do not rely on the institution of a university to provide tools for courses they offer; at least at the small group unit within a course. It is, in a sense, the fullest conceivable realization of Sawyer & Tapia's (2007) observation that the use of the same ICTs often lead to multiple different and paradoxical effects. One such effect is now benign abandonment. The university continues to provide the tools; which in some cases we have studied are expensive, seldom referenced access points for instructor documents.

Addressing Second Order Issues

Second order issues in the finer grained, completely online course context are not resolvable through allocation of resources from within the university or from outside sources like employer support for students. Their resolution requires challenging our understanding of how online pedagogy differs from classroom centered pedagogy; both by the instructor and the students. For example, group work requires more deliberate construction of group practices, and consideration of time zone and work practice differences among members. Assumptions brought to the learning environment from face to face courses, or previous online courses in different contexts do not transfer easily to the online format and therefore surface as infrastructural issues. Students invent their own infrastructure now. One possible resolution is for universities to join students in the abandonment of expensive, highly structured learning environments in favor of more innovative models that enable learning at a distance using tools the students are already familiar with.

Third Order Issues

Individual Interests vs Group Interests: Occasionally Irreconcilable Differences

In some cases, group members could not agree on how to organize themselves, or how their chosen form of organization should be realized in practice. For example, building a common understanding of the group itself is difficult to reconcile when one part of a group perceives a member as dominating, and that member perceives themselves as acting to fill a gap. Each informant in one such group in our study was interviewed three times – at the beginning, middle and end of group work. The dominating member, Melanie, and the non-dominating member, Yasmine, reflect on their group interactions below. First, Melanie describes how, from her perspective, she took a more active role in order to move the group along.

> First Interview "Melanie" - "I think I changed my leadership style to give them what they wanted which was more traditional leadership to tell them what to do. The other thing was the tools. Once I told them what to do and I have the shared view there and was showing them how to create, I think it helped this class. It was my change within me as well as a change in the tools that facilitated the collaboration. Sakai doesn't facilitate, posts do not facilitate collaboration. It is sequential. That is not collaboration, collaboration is simultaneous. …."

Next, Yasmine describes how the collaborative style advocated by Melanie is inefficient, and that the time consumed by collaboration is not efficient, and complains of Melanie's critique of her work:

> Second Interview (Middle of Collaboration) Yasmine - "So that makes me decide we really need a good way to communicate more efficiently, rather than different people have a different opinion and different people work differently. Instead of, at last minute, Melanie said my work its not satisfactory. I have to rework again, like that."

In the final interview, Melanie observes that the suggestions made by Yasmine for tools that would create greater efficiency are ill conceived because they do not consider certain aspects that Melanie values.

> Third Interview "Melanie's subsequent analysis of Yasmine's assertion" - "When you look at things superficially, everything looks related. You don't see the differences. For example, Yasmine had heard about all these different tools that had been used by other people: …. But she did not think of it deeply, given that the team has 3 to 5 hours, can they learn a new tool in that time period? How about downloading and installing, how will that interfere with learning, how will it contribute to learning. She didn't evaluate any of it. I come to find out in today's chat session with the instructor, this new tool is not even available except as a free trial. Apparently what license of permission we were given has expired."

We see these two members of the group, reflecting on the group's evolution in a way that exemplifies irreconcilable differences between them.

Ambiguous Institutional Support for Learning Innovation

Star and Ruhleder describe irreconcilable value differences between people or groups in some context as a level 3 issue; these are inherently political. Mere resource conflicts, or competition between contexts for resources represent level 2 issues because they lack the political dimension. There are times, however, when politics are ambiguous, or are applied invisibly or indirectly. In the case of online learning, decisions related to innovation in learning are necessarily bound up in the relationship between innovation and revenue. If an institution relies heavily on revenue from online graduate education, for example, then anything, including innovation, which disrupts a functioning, profitable model is likely to meet at least tacit resistance.

The revenue generation from online education challenges the traditional function of a university as a source of innovation and invention in society. Technology to support completely online learning is not yet mature; but successful online programs have a stable technology infrastructure. The motivation to innovate is driven by research, not revenue, creating a natural tension in an institution whose mission includes both. Direct resolution of this irresolvable conflict between a modern university's need to generate online revenue and the university's traditional place as a research center lies behind this difficult to see, but important level 3 issue. In our case 2, the institution responds with an ambiguous stance toward technology innovation, which is similar to an issue of support for networked learning identified in the first case.

In case 2, the issue is a lack of institutional allocation of resources to ensure availability of the course management system that is part of a research program. Sakai is offered to instructors "at their own risk", while support for the commercial, revenue generating system is maintained 24x7. While this could be viewed as a level

2 issue of resource prioritization, our observation is that the tension between revenue and research in a modern university is more complex, and ultimately irresolvable. Researchers will favor research & development. Administrators are motivated to optimize revenue, and view technological or pedagogical innovation sceptically. In some ways, this is the tension of the 21st century university, and online learning is at the center of it.

Scaffolding Learning Versus Social Theories of Learning

Completely online learning groups are facilitated in one of two primary ways. First, using carefully structured scaffolds that ensure individual learner progression from stage to stage is a well thought out, rigid process. This approach is focused on the use of technology to support individual learning. Second, there are methods and structuring completely online courses that engage the individual's natural tendencies for social interaction, and leverages that social interaction for learning (Bandura, ??).

Addressing Third Order Issues

Third order issues are difficult to resolve, and oftentimes represent sustained constraints in the development and evolution of infrastructure. For completely online courses we see level three issues occur at the small group practice level, through technology selection and in competing pedagogical viewpoints. Since these effects are made visible through communication, we know they exist; but the individual instances of occurrence are not quickly identified in practice. Viewing infrastructure from the perspective of completely online groups, it is only through building a better understanding of how these groups function, and developing theories of technologically mediated learning that we will be able to ultimately define solutions for level three issues in these contexts. Common understanding of the required technology infrastructure, the need to innovate and the most effective pedagogical strategies for online learning is missing. This is not surprising, since the phenomena itself is new. As in case one, the negotiation of meaning and learning as a social system is required; but in this case such negotiation is a persistent reality, not a phase in development. In a sense, there is no need to align the local communities of practice with institutional structure; online learning groups are persistently self organizing.

DISCUSSION

Two cases have been presented that are complementary in illustrating the kinds of infrastructural issues that can occur when supporting online learning at different levels of granularity (i.e. artifact, practice, and levels). Table 1 compares the infrastructural issues that emerged within the respective learning contexts; issues that are in some way problematic for some group or individual and which impinge directly or indirectly on the quality of online learning in the respective settings.

Table 1. Comparison of Issues

Issue Level	**Case 1: Campus-Based**	**Case 2: Completely Online**
Third order	Pedagogy for online education Multiple meanings of networked learning Institutional mission and values	Individual interests vs. group interests Ambiguous institutional support for learning innovation Scaffolding learning versus

		social theories of learning
Second order	External regimes of accountability Time as a resource Interaction between academic, management and IT contexts	Establishing group practices Time zone and work setting challenges Open and public collaboration tools
First order	Knowledge gaps Technical infrastructure Campus-wide learning about networked learning	Internet connection speeds in rural areas Member adoption of technical infrastructure Task coordination across technologies

The embeddedness of infrastructure. Both cases illustrate how infrastructure, and the task of infrastructuring, is embedded in the relations between practices, technologies, and organizational arrangements; and how these various contexts, and the relations between, impinge on the implementation and use of new media in the respective educational settings. Case 1 illustrates the embeddedness for example of any technological development in the classroom not only in several institutional contexts but also negotiations between them; while Case 2 illustrates the embeddedness of online learning in various spatial, temporal, and technological contexts and the coordination problems that can arise in negotiating across them.

Transparency. As a project concerned with investigating the implementation and evaluation of networked learning at an early stage of its adoption and development Case 1 highlighted many issues that needed to be made transparent in use if the institution was to be ready to deliver online learning e.g. institutional policy on academic incentives and practices, and technical expertise. The challenges of transparency across networks, e.g. diversity of open and public collaboration tools, and context awareness, are manifest in Case 2.

Reach or scope. Taken together the cases illustrate not only the technical but also the various organizational, networked and communicative contexts that are relevant to sustaining infrastructure in educational settings. Therefore consideration of infrastructure in educational settings extends beyond the implementation and use of new media and technologies in the classroom to issues of organizational design, pedagogy, and the communicative practices of learners and teachers in a networked environment.

Learned as part of membership. Case 1 highlights both the beginnings of a community of interest forming around networked learning and its incipient institutionalization and investigating the issues and assumptive contexts relevant to this emerging community of interest formed part of the research of the CBCGW project. By identifying analyzing the issues and perspectives of different groups of stakeholders the CBCGW project was able to make more transparent to each stakeholder and to the institution, the views of "strangers and outsiders [who] encounter infrastructure as a target object to be learned about". Case 2 highlights some of the infrastructural issues that must be attended to by online learners as distributed tasks and group practices are negotiated, formed and sustained at a distance.

Links with conventions of practice. Infrastructure can be linked to existing conventions of practice or it can create the need for new ones. Case 1 illustrates the questioning of existing academic practices, while also highlighting the need for new conventions of practice with respect to organizational and educational design. Case 2 illustrates how online learning links with existing theories of learning; while at the same acknowledging that existing conventions may need to be re-shaped in order to accommodate a new distributed context.

Embodiment of standards. A working infrastructure for implementing new media in education will embody standards or protocols that enable communication within the different relevant contexts in support of online learning e.g. interface, educational processes and assessment, and organizational routines. Case 1 illustrates the discussion needed on the part of organizational actors to develop the standards required; while Case 2 points to the matter of standards as being a feature of infrastructure that distributed learners may find problematic in a way not encountered by campus-based learners. While open and public tools are a welcome development the non-institutionally-supported nature of some software may become problematic on breakdown.

Built on an installed base. No infrastructure for online learning is built de novo; and the conservatism of the installed base is present in both the existing organizational and educational experience and resources available in support of face-to-face teaching. Pushing developments forward in the area of new media in education needs to take account of and negotiate with this installed base.

Becomes visible on breakdown. Taken together the cases illustrate different aspects of infrastructure as they become visible through breakdown. Case 1 illustrates some of the infrastructural issues that arise as standards are being negotiated and the institution develops its readiness; while Case 2 provides examples of how infrastructure for online learning once in place becomes visible to learners and tutors alike through breakdown e.g. through a lack of context awareness or difficulties in forming group practices within a learning setting.

Infrastructural Transcontextual Syndrome

Wenger's learning architecture notwithstanding, Star & Ruhleder also point to some of the paradoxes of attempting to infrastructure across artefacts, practices, and social/organizational arrangements, or as they put it infrastructuring first order, second order and third order categories of learning. Thus in this in case the discontinuity between members' perceptions of knowledge gaps in networked learning (level 1) and an organizational mission focused on research (level 3) appeared problematic for organizational learning; as did the discontinuity between existing external regimes of accountability (level 2) and the organisation's internal innovations in teaching and learning (level 3).

In sum the CBCGW project was able to open up a further channel of communication across the different member groups within the organization and act as an infrastructural device. In Star & Ruhleder's terms an infrastructural context of communication and learning. Some of the paradoxes of attempting to implement collaborative information behaviors within the organization were also highlighted. As a teaching and learning project the project was however only able to act as a resource

for the actors to continue to engage in the organizational transformation that can support the infrastructuring of collaboration in the classroom.

As in the first case, we find a number of discontinuities arising from the paradoxes of attempting to infrastructure across artifacts, practices and social/organizational arrangements. The discontinuity between low bandwidth rural users (Level 1) and the interaction required to establish online group practices (Level 2) appears problematic for effective online learning; as did the discontinuity between those same rural users (Level 1) and the application of social theories of learning (Level 3) which require a great deal of socio-technical interaction to be effective. Further, the application and use of grass roots tools for collaboration (Level 2) faces a tension when encountering group members who put their own interests ahead of the other members of their group (Level 3). The tensions between the practices employed by students and the goals of completely online graduate education create paradoxical tensions between institutions and learning groups, as well as between the universities role as an innovation engine in the economy, and the universities need to generate revenue; paradoxically, innovation and cost reduction could be served by more widespread, institutionally sponsored adoption of the free and open tools students are electing to use anyway – regardless of whether or not their choice is institutionally sanctioned.

CONCLUSION AND IMPLICATIONS

Star and Ruhleder (1996) highlighted two main implications of their study: the need for multidisciplinary teams; and the need for technical user education. Both themes persist in the study conducted here, but in a slightly different key. First we would argue that the composition of the teams cross not only disciplinary but also academic and professional boundaries. The point we want to make however, in keeping with Star and Ruhleder's insight, is that innovation requires a boundary-crossing team that includes members that understand the different contexts (i.e. artefact, practice, social and organisational structures) that impinge on the development and sustainability of the innovation. Second, where Star and Ruhleder's (1996) point to the need to alter the character of technical user education, we would argue that in a current age where there is a plethora of user-friendly light applications available, this becomes less of an issue. Nevertheless as alluded to earlier while a single system lacking in transparency may have been in the norm in the early days of the Internet, the embarrassment of riches creates its own problems. What continues to be an issue is the communicative context between users and between learners when different applications are used. While technically interoperable users still need to understand the particular nature and possibilities of the applications that others are using. In sum, issues of multiple contexts and of communication persist. Therefore, an overriding lesson from our analysis is the belief that whatever the context of application infrastructural issues will continue to be problematic; and that a need for infrastructuring will persist. Whatever the particular mix of technologies, human actions been supported, and constraining or enabling structures there will exist a need to resolve these issues in situ and within the particular communicative context of the actors involved.

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