CENTRES, PERIPHERIES AND ELECTRONIC COMMUNICATION:

Changing Work Practice Boundaries

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Abstract

In this paper, I explore what we might mean by the phrase "crossing work practice boundaries by means of electronic communication". The focus is on the work practice boundaries, and the transformational effects of electronic communication on such boundaries. I begin by defining work practices with respect to the social world or activity system communities for whom such practices make sense. Taking up Strauss' suggestion that peripheries arouse more appropriate imagery for the variation and fluidity of social world boundaries, I propose a metaphor of boundary in terms of centres and peripheries, where peripheries can be characterized in a number of ways including: the degrees of commitment, the limits of communication and the levels of participation. Vignettes from three case studies illustrate some of the transformational effects of electronic communication on the relationships between a centre and its peripheries, on the external relationships among centres and their peripheries, and on the relationship of work practice boundaries to other boundary forms. In designing support for social worlds, a centre-periphery perspective could allow for more explicit account of the fluidity of work practice boundaries and the ways in which these might be affected by electronic communication.

Keywords:

Activity theory, social worlds, work practice, boundary, centre, periphery, case study

INTRODUCTION

At the 1998 Congress of the International Society for Cultural Research and Activity Theory (ISCRAT), Kari Kuutti proposed and chaired a session titled "Crossing boundaries between work practices by means of electronic communication". As a computer scientist, my first instinct was to reinterpret the title as "electronic communication as a means to cross work practice boundaries" – the emphasis being on the electronic communication [1], on systems and artefacts. This is a more familiar emphasis as evidenced in many excellent discussions, for example, on the use of systems or artefacts to mediate boundary crossing in design (Bertelsen, 1996; Tuikka, 1997).

What if we were to leave the emphasis on "crossing boundaries"? Boundaries are so commonplace a notion that we can take them for granted. We experience boundary forms every day – physical boundaries like walls and doors; organisational boundaries typified by departmental divisions and access permissions; country boundaries that need to be defended by border patrols; and so on. Containment. Control. Edge conditions.

What do we mean though when we talk about "crossing boundaries between work practices by means of electronic communication"? Are work practice boundaries a similar sort of thing to the boundary forms we experience every day? Does crossing happen in a similar sort of way? And what are the effects of boundary crossing?

I want to take a complementary point of view to discussions of means for boundary crossing and focus primarily on the work practices that these electronic communications reflect and support. Rather than working with an implicit sense of boundary as edge, the goal of this discussion is to make explicit a different metaphor of boundary that is more applicable to socially-situated work practices. By exploring the nature of work practice in the first instance, I can then go on to explore the nature of work practice boundaries and the transformational effects of crossing those boundaries by means of electronic communication.

On the nature of work practice boundaries, I will define these, not in terms of edge conditions, but in terms of centres and peripheries. I will be arguing that work practice boundaries are best interpreted in relation to social world centres, or in Activity Theory terms, the object of the activity. This is because work practices are carried out by members of a social world or community in working towards their shared object. The notion of centres and peripheries gives rise to the effect of multiple boundaries by degrees and limits of commitment, communication, and/or participation with respect to this object centre.

On the transformational effects of electronic communication on crossing work practice boundaries, I want to explore not just the moment of boundary crossing but the nature of that breach in the first place and the consequent boundary-related processes that happen by virtue of that crossing. This includes exploring the inter-relationship with other boundary forms such as spatial or organisational boundaries.

Vignettes from three different case studies help to illustrate the nature of boundaries and different boundary effects. The case studies show that electronic communication can change the internal relationships between a centre and its peripheries, and the external relationships between centres and peripheries. One of the case studies also demonstrates that electronic communication is a necessary but not sufficient condition for boundary crossing. Another shows that electronic communication can have unexpected impacts on other previously congruent centres, such as or-

ganisational centres.

For designers of systems providing the electronic means to cross work practice boundaries, I hope that this discussion will help make the dynamic and variable nature of socially-situated boundaries more visible in the design process. This extends the design focus beyond the functional attributes of the system as boundary artefact or boundary support, to also be cognisant of the effects that might ensue from the crossing of those boundaries.

The extent to which we continue to use the term work practice boundary in its default sense as stable edge is the extent to which we fail to properly explore and understand the nature of those edges and the consequent effect of boundary crossing in a social context. That is, to use the term 'boundary' as an edge metaphor is to render invisible and unproblematic the very nature of the boundary itself and the effect that electronic communication can have in facilitating border crossing and changing the nature of the borders themselves.

Chapter outline

This chapter is structured as follows. In Section 2, *work practices* are defined with respect to the social world or community undertaking them in context. Picking up on Strauss' (1993) claim that the notion of *boundaries* can arouse irrelevant imagery for social worlds, I go on in Section 3 to explore common boundary experiences and characterise the dominant metaphor of boundary as an edge condition. In Section 4, I propose a different metaphor for work practice boundaries using notions of centre and periphery that are more relevant for social worlds.

Having explored the nature of work practices and associated boundaries, I then turn attention to *boundary crossing*. In Section 5, previous work on the mediation of boundaries and boundary crossing is discussed. From the complementary perspective of the work practice that is being mediated, vignettes from three different case studies are presented in Sections 6, 7 and 8 to explore the nature of boundary crossing using the language of centres and peripheries. The different transformational effects on boundaries and work practices observed in the studies are summarised in Section 9. In Section 10, I draw out issues when designing support for centres and peripheries, before concluding in Section 11.

WORK PRACTICES, ACTIVITY SYSTEMS AND SOCIAL WORLDS

Concepts from Activity Theory and Strauss' Theory of Action (1993) are useful starting points for understanding the nature of work practices and evolving a metaphor to account for work practice boundaries. These theories complement each other in many ways (Star, 1996). Both argue for complex units of analyses around some shared purpose or object and incorporate material, social and historical aspects. Both also highlight the centrality of time and change in action. I acknowledge that there are also many differences between the theories, and that there are different emphases, languages, and concerns. I take a more pragmatic approach here to focus on what is in common, and to use the differences in complementary ways.

Social worlds and activity systems

In his Theory of Action, Strauss (1993) defines a social world as a group of individuals (or groups), bonded by a common goal or commitment to collective action. This goal might be explicit or implicit, well defined or poorly defined, and the subject of ongoing negotiation, evolution and refinement. Social worlds can be composed of sub-worlds which themselves may be composed of sub-worlds and so on. Sites and means (tools, artefacts, etc.) are needed to facilitate the shared interactions of the world, and to provide shared context (Strauss, 1978).

A social world and its site and means are analogous to the activity system in Activity Theory. An activity system is the primary unit of analysis in Activity Theory. It "comprises the individual practitioner, the colleagues and co-workers of the workplace community, the conceptual and practical tools, and the shared objects as a unified dynamic whole." (Engeström, 1991, p.267). The distinguishing feature of one activity system from another is the shared object.

Work practices can be defined then with respect to these complex units constituted around some shared goal. My position here is that to understand what we might mean by work practice boundaries, we first need to understand the work practice. To understand work practice, we need to understand the context in which the work practice is defined and undertaken because all actions are socially and materially situated, and embedded in interactions and systems of meaning (Strauss 1993).

To ground that contextual understanding, I start with the people undertaking those work practices and for whom the work practices make sense. Strauss states: "social worlds provide the *contextual* conditions for *action* and its immediate meaning" (1993, p. 159, emphasis in the original). As such, social worlds constitute "the fundamental building block(s) of collective action" (Clarke, 1991, p. 131). Bødker (1991) similarly states: "A group of human beings who conduct a collective activity with a specific object or goal shares a *practice*." (p. 28; emphasis in the original). This is not to ignore the site and means, the material and historical aspects of context, but is an attempt to more appropriately ground work practices with those who undertake them.

Thus we can say that work practices are defined with respect to the social system sharing a collective goal, as mediated and shaped by the material system (however those conditions and means are defined), as patterned and evolved over time.

Time and Change

In Strauss' Theory of Action, the "processual nature of interaction" and the "continual permutation of action" over time are core principals captured in his concept of trajectory. This accounts for the social world and its site and means in action over time: past, present and future; cycles, rhythms and phases; the practical accomplishment of work; routines, articulation, contingencies and breakdowns; information flows; workflows; and so on.

An activity system too is defined as being inherently dynamic and evolving. A fundamental principal of Developmental Work Research (Engeström, 1991), derived from Activity Theory, is "the explanation of time and change" whereby "the evolution and change of activity systems may be depicted as cycles of expansive learning" (p. 269). Contradictions are primary drivers in this learning cycle. As stated by Engeström (op.cit., p. 286), "Expansive learning means that not only the individual participants change in the process; they also change their collective practice and its

institutional frames". The effects of electronic communication will later be interpreted within this change process.

Characterisation of social worlds

What Strauss' theory offers in complement to Activity Theory is a rich conceptualisation of the nature of the social worlds within which we define work practices and will ultimately define work practice boundaries. I suggest that the conceptualisations could be applied equally well to the workplace communities in activity systems.

Strauss describes social world membership as highly variable and dynamic, both in terms of what each member's commitment entails, and in terms of who constitutes the members at any point in time. For example, membership of social worlds can be considered along a number of dimensions: size, longevity, the organisation of members into roles, the formalisation of membership processes, and many more. Thus membership can range from informal and/or transient to formal and/or persistent. People also tend to be members of multiple social worlds simultaneously and have to juggle and negotiate their different levels of involvement in each of those worlds across time and space.

The most important bounding factor for any world is not spatial or organisational structure or formal membership but the *limit of effective communication* (Shibutani, 1955). This limit can be either technological, i.e., people can only form a social world with others they can reach via some medium of communication. The limit can also be ontological or lexical, i.e., people can only communicate effectively when they share a common language and understand what it is each other is saying. Some social worlds can be identifiable with certain spaces or be aligned with formal organisational structures. Other social worlds are more dynamically or informally characterised.

A METAPHOR FOR WORK PRACTICE BOUNDARIES?

What then of work practice boundaries? Strauss states that "one property that seems particularly difficult for some sociologists to imagine is that of the relatively fluid boundaries characteristic of many (social) worlds" (1993, p. 213). He goes on to argue that failure to understand the variation and relative fluidity of social world boundaries can lead to irrelevant imagery. Strauss suggests that "perhaps it would be better to discard the concept here of boundaries and substitute something like peripheries, and thus avoid arousing irrelevant imagery", but laments that "alas, 'boundaries' is too well established" (p. 214).

What is the irrelevant boundary imagery to which Strauss refers? In the following I suggest that the imagery arises from the predominant experience we have of boundary as a relatively stable fixed edge condition.

DOMINANT BOUNDARY METAPHORS

Boundaries provide powerful mechanisms to structure our environments, and by definition, to mediate, shape, and be shaped by our interaction there. The following are examples of how the term 'boundary' is used in different ways by different people for different purposes.

Physical boundaries

Physical boundaries exist in many forms. There are country borders, property boundaries, room boundaries, boundaries in the game of cricket, and so on. These boundaries are used to afford a variety of functions – to enclose space, to distinguish regions, to give containment. Boundaries can be used to provide security and privacy, to control who or what can enter or leave the enclosed space and how that access happens, to differentiate activities and purposes. Boundaries can be drawn on maps, given locatable addresses, and made visible by structures such as walls, or representations such as lines or the arrangement of furnishings.

Virtual boundaries replicating physical boundary effects

The term 'boundaries' has also been appropriated in a variety of ways in CSCW (and related) literature to replicate many of the effects of physical boundaries and to instantiate boundary forms in technology.

Boundary affordances by analogy

Drawing on the observation that rooms provide a very effective form of boundary and enclosure in the physical world, many collaboration environments have been built using a rooms-based metaphor to provide similar affordances in the virtual domain. Some of these systems have focussed more on the graphical representation of virtual spaces as shared working environments, e.g., 2-D or 3-D representations of rooms or offices as in GroupDesk (Fuchs et al., 1995), TeamRooms (Roseman and Greenberg, 1996), Diva (Sohlenkamp and Chwelos, 1994), and Dive (Benford and Fahlen, 1993). As such they use the analogy of space to draw on our familiarity and intuitions about interactions in physical rooms to shape our interactions in virtual rooms.

Boundaries as container

In our prototype system, wOrlds (Fitzpatrick et al.,1995), we aimed to support a notion of locale as a shared place for group interaction, i.e., place capturing the broader context of that action. Inadvertently, we ended up deploying a 2-D rooms-based metaphor embodying boundary and containment notions of in and out, here or there, one place at a time, i.e., 'boundary as container'. A fuller critique of the underlying spatial metaphor of the wOrlds system is presented in Kaplan et al. (1997) and Fitzpatrick (1998).

Boundaries as security

The developers of the Mushroom framework (Kindberg, 1996), on the other hand, argue that boundary and space are the two most important features of the rooms metaphor for the support of collaboration. Their boundaries afford the "security and integrity guarantees for shared objects and communication" while space affords mutual awareness. Boundary crossing is the key mechanism by which security and integrity constraints are activated. In the Mrooms system built on their framework, boundaries are implemented as "security firewalls and concurrency control and integrity firewalls": when a user or object icon is dragged across an Mroom's graphical boundary, the "boundary object consults the corresponding space object (which in turn can consult the dragged object) to decide whether crossing is possible, and if so what the effect is.".

Boundaries to define groups and pattern time

Johnson-Lenz and Johnson-Lenz (1991), on the other hand, begin the work of defining 'boundaries' in relation to groups. They do so based on the observation that "Rhythms, boundaries and containers are primitives - universal, fundamental patterns from which all life is built - including our social life" (emphasis in the original). They argue that these same patterns can "connect groupware mechanisms and germinal open spaces (context) in a creative whole ... as forms to persuade rather than control, to hold that life in a flexible way" (p. 402). Boundaries "define group membership, delineate group identity; mark rhythms, beginnings, endings" (p. 405). Of most interest to the current discussion, they go on to note that "living boundaries are inherently dynamic, varying along the dimensions of permeability and flexibility" and can be applied to "both spatial and temporal boundaries" (p. 407).

Such variability, however, is not evident in the way they interpret and implement boundaries in computer-support for workshop activities. Virtual boundaries are used to set up clearly defined membership criteria (in/out) and to create interaction rhythms using a temporal gate preventing "members from moving on to the next round until it is opened" (p. 411). In these examples, they use electronic communication to implement explicit discrete boundary forms to pattern the interactions of a group in a particular way.

While their example does not explore the richness of boundaries as they had previously defined them, their discussion does point to the integral relationship between boundaries in the social world and boundaries in the mechanisms and contexts that support social life.

A metaphor of boundary as edge condition

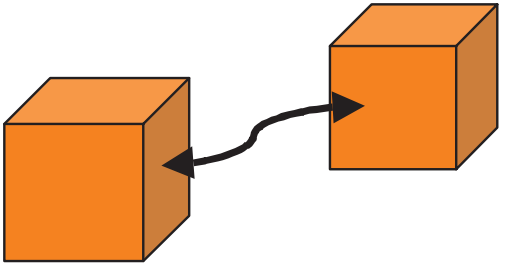
Most of these conceptualisations of boundaries focus primarily on boundary forms as enacted in physical or virtual space. The dominant metaphor is boundary as edge condition or border or barrier. This brings connotations of boundaries as being relatively stable and discrete. Property boundaries, for example, can be measured in space using a stable coordinate set. They are situated in the physical realm. Virtual boundaries replicate the effects of physical boundaries to provide security, to contain, to constrain, some with more emphasis on one thing than another. They can be encoded in software or encapsulated by firewalls.

While many of the uses of boundary just discussed explicitly refer to the socially-situated nature of these devices and their social effects, the boundary form was external to the work practice it was supporting or shaped by. The direction of influence of all these boundary forms is primarily to shape or control social interaction through environmental structures.

A particular language has evolved around the notion of boundary as edge condition. We talk of being inside or outside, here or there, in one place at a time; we talk of crossing over a boundary. Given this metaphor, it is easy to imagine that boundary crossing is facilitated in the same way that a border gate facilitates crossing from one property to the next. Or a bridge facilitates the crossing of two boundaries that were previously disconnected. Or a password facilitates going past the firewall of a computer network. Or a ball crosses over the rope at the boundary of the cricket field.

The language reflects the underlying metaphor of boundaries as relatively stable discrete edge conditions. The crossing is achieved by breaching or traversing those edges, as depicted in Figure 1.

Figure 1. Boundaries as discrete edges to be crossed



Towards a metaphor for work practice boundaries

While we might readily agree that work practice boundaries are different to physical or virtual boundaries, there is not yet a strong enough conceptualisation of socially-situated borders to challenge the dominant model of boundary as edge and the irrelevant images this model arouses. This is not to reject the affordances that can be supported by using the dominant metaphor, e.g., security, privacy, identity, separation, control, hiding unnecessary detail, etc. Rather, it is saying that the *edge metaphor lacks the richness to capture the dynamicity and fluidity of social boundaries*. Without a richer conceptualisation of such boundaries, it is easy by default to implicitly reflect back to work practices the connotations of the external boundary metaphor. A different metaphor is needed.

BOUNDARIES AS CENTRE-PERIPHERY RELATIONSHIPS

Strauss' suggestion that the concept of boundaries for social worlds should be substituted with something like *peripheries* begins to point us in the direction of a more appropriate metaphor for work practice boundaries. His conceptualisation of social worlds also starts to give us ways of talking about the variability and fluidity of these peripheries.

Thus, the *framing question* for this chapter is: where would it take us if we were to use the concept of 'boundaries as peripheries' rather than 'boundaries as edges' for talking about work practices and the effects of electronic communication?

In this section, I will start to define a metaphor of *boundaries as centre and peripheries*, where the effects of boundaries is given by peripheries in proximity relationships to the centre. Using this different conceptualisation of boundaries, I will go on in subsequent sections to explore the transformational effects of electronic communication on the nature of boundaries and boundary crossing – firstly in existing studies focussing on boundary forms and boundary objects, and secondly as illustrated with vignettes from three different case studies.

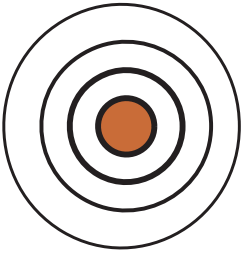
Peripheries as proximity relationships to a centre

An immediate observation of Strauss' suggestion for peripheries is that the concept of periphery is a relative term, i.e., a periphery is periphery only in relationship to something at its centre. For social worlds and communities, this centre can be characterised by their distinguishing shared object or purpose. Work practice peripheries then can be defined with respect to this centre. The term centre is used here, not as a defined point, but as an attractor that associates and gives sense to the relevant people, sites and means for achieving the goal. In this, I share Lave and Wenger's (1991) concern about an implied notion of centre as some fixed or definable end-point to which one makes a linear progression from the periphery.

The notion of periphery implies location and variation. In this regard, Lave and Wenger's description of 'peripherality', while directed towards legitimate peripheral participation as a form of learning, holds equally for work practice boundaries:

> "Peripherality suggests that there are multiple, varied, more- or less-engaged and -inclusive ways of being located in the fields of participation defined by a community. Peripheral participation is about being located in the social world." (1991, pp. 35-36)

Figure 2. A representation of a centre and its peripheries



Thus we can talk of boundaries as being in *proximity relationships* to some centre. This is represented in abstract form in Figure 2. The language of 'boundaries as peripheries' now becomes more than binary notions of 'in or out'. We can also talk of continuities, of something being more or less central and more or less marginal. We can talk about variation and movement along the continuum towards or away from the centre.

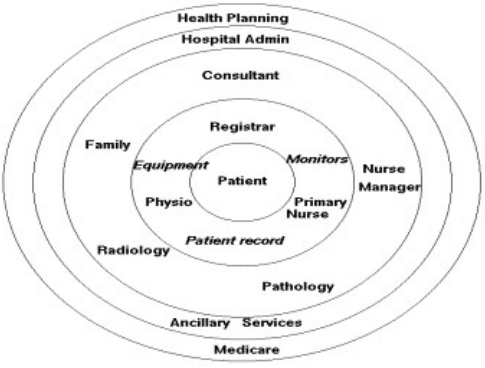
A consequent observation is that the notion of work practice peripheries in proximity relationships to a social world centre implies the *effect of multiple boundaries* via degrees and limits in the relationships. That is, different proximity relationships can define different arbitrary boundaries at points where the continuum between 'more central' to 'more peripheral' are better differentiated than others.

For example, Figure 3 depicts the social world that exists around the care of a patient in a hospital. The people and resources in closest relationship to the centre are more centrally involved in the care of the patient than those in the outer rings, who have more of a peripheral interest or need more of an overview picture of the care activities.

(We note here that we use the terms 'centre and peripheries' in a different way to Brown and Duguid's (1994) use of the terms. Their periphery is related to the artefact centre and its more

canonical forms, where periphery includes those things that are in side vision or background or out of conscious focus. Our centre refers to the social world itself not an artefact, though the centre could be mediated by an artefact. We do, however, strongly concur with some of their general characterisation of centres and peripheries where they make statements such as "centre-periphery relationships are neither crisp nor theoretical. Rather they are indeterminate and practical, depending on practice and changing dynamically with it" (p. 7).)

Figure 3. A social world centred around the care of a patient

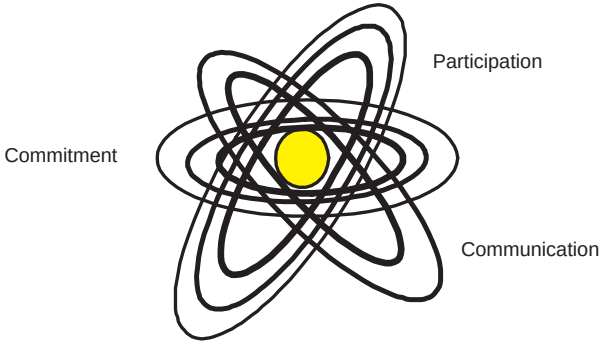


Multiple peripheries in multiple dimensions

Strauss' conceptualisation of social worlds, overviewed in Section 2.3, implies further that the variation of peripheries as boundaries in a social world can be characterised in a number of ways, especially by the following:

- degrees of commitment
- limits of communication
- levels of participation

Figure 4. A centre with peripheries along multiple dimensions, e.g., commitment, communication, and participation



Thus there are *multiple dimensions* along which the effect of multiple boundaries can be seen in a social world, as depicted in Figure 4. Differentiated peripheries might exist around the *degree of commitment* to the social world purpose. This can vary from intense commitment to wavering commitment. Differentiated peripheries can exist according to the *limits of communication*. These might vary from co-located face-to-face communication to geographically and possibly temporally dispersed communication via different technological media. Differentiated peripheries can also be described according to different *levels of participation* – these can vary from actively involved in core activities to passively involved in marginal activities. A person's 'location' with respect to the centre can be abstractly defined in this multidimensional space.

Moreover, the varying levels of commitment, communication and participation, i.e., the movement between the centre and the peripheries along these dimensions, can be highly dynamic in space and time: across time with the temporal ebbs and flows, phases and cycles of social world activities; and across space as people and artefacts move around the sites used by the social world to support their work practices. As Johnson and Lenz state: "living boundaries are inherently dynamic, varying along the dimensions of permeability and flexibility" (1991, p. 407). Lave and Wenger too argue that "*Changing* locations and perspectives are part of actors' learning trajectories, developing identities, and forms of memberships." (1991, p. 36; emphasis in the original).

This highlights another important point about centres and peripheries – they do not exist as objective single realities but are always defined from some relevant perspective, reflecting the constantly evolving multi-voiced and multi-layered nature of activities.

It should be noted that the notion of 'boundary as periphery' does not exclude relatively fixed impermeable boundaries, or single well-defined boundaries. These could be regarded as the trivial cases of peripheries. Many social worlds have far more complex, fluid, and dynamic boundaries, differentiating them from hard physical-realm boundaries. The term 'peripheries' arouses imagery far more appropriate for such socially-situated boundary forms, be they single and fixed or complex and dynamic.

BOUNDARY CROSSING: MEDIATION AND TRANSFORMATION

Having defined work practices boundaries in terms of peripheries around the social world centre along multiple dimensions, what does it mean to cross these boundaries by means of electronic communication?

This question cannot be answered without reference to the broader context, both material and historical/developmental, within which the work is mediated, shaped and transformed over time, i.e., work practices do not exist as independent entities. Hence implied in this question is an understanding of how boundary forms and boundary crossing are mediated as well as the consequent transformational effects on work practice boundaries and their mediational artefacts.

Review of mediation of boundaries and boundary crossing

The issues of how boundaries are inscribed and mediated by various means, and how different artefacts support boundary crossing have been the focus of various discussions. Many of these,

e.g., (Bardram, 1997; Bertelsen, 1996; Bødker, 1998a, 1998b), come from an Activity Theory point of view; this key emphasis on mediation is a complementary strength of Activity Theory when compared to Strauss' theory.

Star (1989) identifies a class of objects called boundary objects to facilitate problem solving across heterogeneous contexts (or social worlds or activity systems). Boundary objects are distinguished by being "both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." (p. 46). This concept has since been widely adopted and used. Bardram (1997), for example, describes the boundary object role that a Patient Scheduler plays in supporting communication, sharing and planning between different wards and departments within a hospital.

Design work is also a process where people from multiple social worlds or activity systems can be involved, and where artefacts can play an important mediational role in supporting communication and interaction between stakeholders. Bødker (1998a) talks of design itself as a boundary-crossing activity, and explores the way in which artefacts mediate computer design as boundary crossing. Similar to boundary objects, design artefacts support communication and the sharing of ideas within the design group (meeting local needs), across different activities and practices of designers and users (meeting needs across sites), as well as across different temporal and historical contexts by touching upon future users and practices.

Similarly, Bertelsen (1996) states that "Design artefacts are boundary objects because they traverse the heterogeneous activity systems involved in the design process." (p. 99). He describes the boundary object role that a festival checklist plays between people from different activity systems, e.g., management, lighting, sound and so on, and he explores design as the transformation process of this shared artefact.

In reviewing experiences with different representational forms in design, Bødker (1998b) cautions however that representations can be "limited with respect to their boundary crossing capabilities" and that a range of representations might be needed to "support different purposes and perspectives in the design activity".

Tellioglu and Wagner (1997) are also concerned with boundaries and tools, specifically the configuration management tools of their case studies that can not only "support cooperation across multiple organisational and social boundaries" (p. 252) but also be "respectful of regionalisations". Their use of the term 'regionalisation' is drawn from Giddens (1984), and refers to the physical, social or organisational boundaries that are internal to a specific place.

New concepts are emerging to describe some of the interactional forms that emerge across boundaries. Strauss (Clarke, 1991; Strauss, 1993) defines an 'arena' where different social worlds interact together around some common issue. Engeström et al (1999) identify 'knots' and 'knotworking' as another type of interaction between people from different activity systems. Knotworking involves cross-group interactions that are of relatively short duration, often repeated as a pattern, and not attributable to any centre of control. This is in contrast to the more stable or longer-lived design activities or situations that boundary objects might support across groups. Nardi et al (2000) have coined the term 'intensional networks' to describe collectives that are "put together through the assemblage of people found through personal networks". As stated by the authors, these networks tend to involve longer-term relationships in more flexible and looser configura-

tions than knots.

In most of these cases, the concern is for supporting interaction between multiple people, activity systems or social worlds. While boundary is used in the sense of work and use contexts rather than physical boundaries, the focus of the discussions tends to be not so much on the nature of the boundaries as on the interactional forms or on the boundary artefacts, whether physical or virtual, and their creation, evolution and use in the environment supporting multi-party interactions.

From a different perspective, Brown and Duguid (1994) talk of artefacts as being border resources. More specifically, they describe the border resources of the artefact itself, and how those resources support the shared use of the artefact. Here they use 'border' as being peripheral to the core artefact, i.e., peripheral in the visual sense of being part of the periphery not the focus. People use these border resources to interpret the genre of the artefact and hence the associated social practices.

While Brown and Duguid also describe the use of artefacts for supporting social practice, their definition of border, while artefact-based, is socially constructed. They define border as the "region where centre and periphery meet" (p. 8), the border being distinct from the rest of the periphery by "playing a socially recognized role in the artefact's use". It is not "simply an indisputable physical feature ... but as a physical manifestation of the complex social practices and conventions, it is susceptible to alteration and negotiation" (p. 8).

Tellioglu and Wagner (1997) pick up more specifically on the relationship between their internal regional borders and work practices but they focus on the spatialisation of the boundary: "Regionalisation can be described in spatial terms, saying that the furnishings of different regions and their physical distance accentuate, solidify, and create differences of work practices and knowledges, of culture and identity." (p. 253). This spatialisation of regions can be interpreted as one way in which multiple boundaries can be inscribed in, and mediated by, space.

Moving to a complementary focus on boundaries and transformation

The studies just discussed provide insightful examples of the ways in which boundary crossing between multiple activities can be mediated. However, I interpret their focus as being more directly on the material forms that mediate boundaries or boundary crossing than on the nature of the socially-situated boundaries *per se*. Also, the mediation of the multiple boundaries that are internal to a single world or activity is not directly addressed.

In the following case study discussions, I want to take a complementary point of view and focus on the nature of the work practice boundaries using the language of centres and peripheries, and then go on to explore how these boundaries change as a result of boundary crossing mediated by electronic communication. It will be complementary because mediational form and practice are mutually defined and constituted – one cannot exist without the other. Specifically, the contribution will be towards a richer conceptualisation of work practice boundaries both internal to an activity or social world, and between worlds. It will also be complementary by following through on how work practice boundaries are transformed as a consequence of the crossing that is mediated by these boundary artefacts. Exploration from these different points of emphasis will help build richer pictures of the complex contexts of activity.

The three case studies [2] involve a group of distributed researchers called the Internet Exploration Unit (IEU), an Intensive Care telehealth project, and a teleradiology project. The nature of the boundaries and the mediational role of electronic communication will be explored. The range of resulting boundary effects will point to ways in which the language around the notion of 'boundary crossing' can be extended to describe boundary and hence work practice transformations. Instead of simply talking about being in or out, or crossing over, we can characterise boundary crossing more richly as, for example, extending the social world periphery, or changing the proximity relationships to the centre, or facilitating the emergence of new centres, or changing the relationship between centres, e.g., to intersect, merge, strengthen, weaken, and so on. While I will predominantly use social world concepts from Strauss' Theory of Action in the descriptions, I have already pointed to ways in which Activity Theory concepts could be similarly applied.

CASE 1: INTENSIVE CARE TELEHEALTH

The Telehealth project involved the Intensive Care Units (ICUs) of three hospitals – one is a tertiary centre in a metropolitan city, the other two are smaller regional hospitals. Consultations via telephone between clinicians at the regional centres to experts at the tertiary centre are commonplace. These usually involve the regional doctor seeking support for the diagnosis and management of a critically ill patient, or requesting transfer of the patient to the tertiary centre.

While this works well enough often enough, problems do arise. For example, patients are often transferred inappropriately, optimal care is often not instituted early enough, and the receiving clinicians are often insufficiently prepared for the patient because they are given only a partial or even incorrect assessment of the patient's true condition. At the initiative of the clinicians, a project [3] was established to provide advanced telecommunications to improve the quality of the information that could be conveyed during these remote consultations.

Changing the nature of inter-ICU consultations

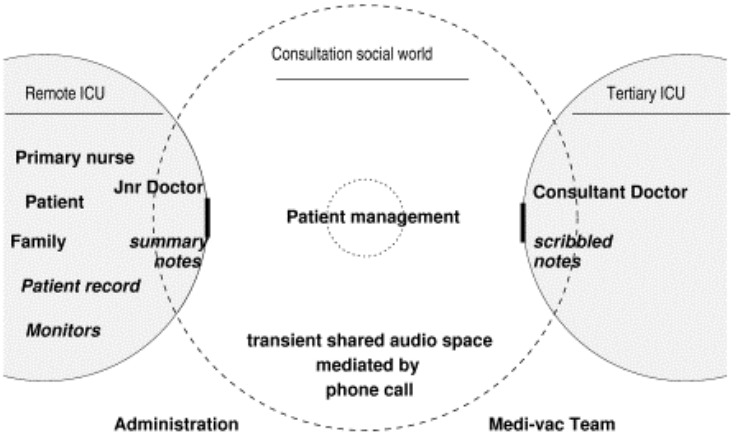
Doctors at the two regional ICUs already consult their peers at the tertiary ICU. The current medium of communication is the telephone. When supporting documents, such as x-rays or test results, need to be shared, they are transported between sites by courier.

We can characterise this consultation as a transient social world that is formed around the need to access expertise about the management of a critically ill patient, as represented in Figure 5. The two central participants are the regional doctor and the tertiary doctor who are drawn from the separate ICU worlds. There are also others who participate in a more peripheral way, e.g., the regional nurse who is looking after the patient, the nurses at the tertiary unit who may be taking over the care of the patient if he is transferred, the family who anxiously await the outcome of the call, any family or staff member from whom the regional doctor seeks information in response to questioning from the tertiary doctor, and so on. Even more peripheral are the medi-vac team who might be involved in the transfer of the patient between facilities, the hospital administration who have to be concerned for the resource implications of care decisions, and so on.

The consultation social world, however transient, can be formed because the medium of the telephone facilitates the merging of the peripheries of the participating ICUs for a period of time – setting up a context for boundary crossing of information and, in the case of a transfer, the physi-

cal boundary crossing by the patient him/herself at some later time. In this way it could also be called an example of Engeström et al's knotworking (1999).

Figure 5. Inter-ICU consultation with limited participation at the peripheries.



The nature of telephone communication, however, also defines the limit of effective communication in the consultation world. Firstly, only two people can participate directly and fully in the call. Both need to be available at the same time at specific locations. Others in the units who are physically co-present can potentially overhear one side of the call and participate indirectly. Yet others who are potentially impacted upon by the call have to rely on the participating doctors to pass on the necessary information after the call.

Secondly, the narrow bandwidth limits the exchange of information to that which can be characterised verbally. Consequently, the effectiveness of the consultation is largely reliant on the ability of the regional doctor to paint rich word pictures of the patient's condition. It also relies on the level of trust between the doctors as to whether the tertiary doctor believes the regional doctor's interpretation of the patient's condition.

This is in contrast to in-house consultations that take place around the patient's bedside where all participating clinicians have shared access to the rich environment of the patient and associated monitors, the patient record, other care providers, and the general milieu of the ward.

As stated earlier, this form of remote consultation can sometimes result in misdiagnosis, mismanagement, or inappropriate transfer of patients.

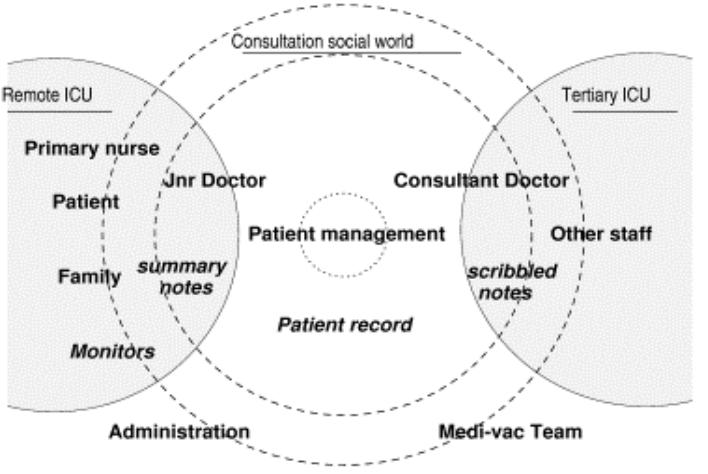
Extending the limits of effective communication

Following extensive consultation, the clinicians decided to establish video-conferencing and data sharing capabilities between sites using ISDN and off-the-shelf hardware and software technologies. Appropriately configured computers, a digital camera and a flat-bed scanner were installed on mobile trolleys in each unit. This has had significant boundary effects on consultation work practices.

Firstly, by extending the limits of communication, the *periphery of the consultation world is also extended* to allow more than one person to actively participate at each end, as shown in Figure 6. Alternatively, we could say that it opens up the peripheries of the ICUs to enable greater participation across the boundaries. The regional doctor who initiates the consultation and the tertiary doctor being consulted are still the key participants in the call but now they can directly involve others as needed.

For example, other staff members have been co-opted to provide different areas of professional expertise or to provide more input on the patient's condition. The patient's family have become involved, for example, to answer questions about the patient's lifestyle or to meet the staff at the tertiary unit who will be taking over the care of their loved one. Patients themselves have also participated in the call.

Figure 6. Inter-ICU consultation with extended participation and communication.



Secondly, the network, video-conferencing and data-sharing capabilities increase the available bandwidth and enrich the quality and quantity of information that can be shared within the consultation. Alternatively, we can characterise this as *making the peripheries of the ICU worlds more permeable and accessible* to the other, thus increasing the exchange of information across the borders. Data including x-rays, scan images, pathology results, indeed almost any relevant information, can be scanned into the computer prior to the video-conference, and can be viewed and manipulated simultaneously by all participants. The tertiary doctor no longer has to rely entirely on the ability of the regional doctor to relay the patient's condition because she can now see for herself. As one of the doctors stated in an interview about using the system, "seeing is believing" and another, "you know that what you're seeing is what you will be getting".

Extending the periphery across space and time

The relationship of consultation work practice boundaries *across space* have also been affected by the introduction of the video-conferencing technology. Now that the equipment is kept on a mobile trolley, the consultation can take place from any physical location within distance of power point and network connections. The boundary of the call is no longer linked with the physical location of the telephone. Not only can different consultations take place from different locations but a single consultation can involve multiple locations; the trolley is often wheeled from its usual spot to the bedside to show live video of the patient or their monitors.

The boundaries of the consultation *across* time have also been made fuzzier, decreasing the reliance on strictly synchronous interaction and extending the temporal periphery of the consultation. In telephone calls, there is no persistent or accurate representation of shared data beyond the call except for scribbled notes that the participating doctors might make during the discussion. Now that shared source data can be saved and stored at the tertiary site, all the relevant people no longer have to be available at the same time since they can access the data at a later time. This is particularly useful in a hospital environment that is very much event-driven: a common scenario is the doctor's pager sounding with an urgent call to the operating theatre just as she is about to participate in a consultation, or where a more junior tertiary doctor needs to conduct a secondary consultation with their own consultant to verify the course of action decided upon during the call.

The phases of the consultation process across time has also been significantly shortened. Previously, it was not unusual for a consultation cycle to take days by the time a call was made, x-rays couriered to the tertiary clinician, further tests requested and undertaken, the new results couriered again to the tertiary centre, a decision made, and a patient transferred. This can now be reduced to a matter of hours.

Unexpected boundary effects

The easiest part of the ICU telehealth project was installing the networks and setting up the hardware and software. The more significant and critical challenge was how to integrate the technologies into the everyday work practices of clinicians who are extremely busy, dealing with multiple competing demands, and wanting to focus on time-critical patient care, not the tools to deliver that care.

To help the clinicians become familiar with the technology, a number of educational and peer support activities were established across sites, including ward rounds, inservice education sessions and management meetings. This resulted in some unexpected boundary effects, both across units and within professional groups.

The video conferencing technology facilitated the emergence of *new transient social worlds drawn from the merged peripheries* of the participating ICUs. The most obvious benefit from such interactions is the sharing of expertise and resources, with particular advantages for the regional units – it is expected that having better-educated clinicians will ultimately translate to better patient care at the local unit.

A less obvious benefit has been the strengthening and growth of peer networks across the units. Previously, the ICUs operated independently from each other. Interaction between the units was limited to occasional encounters between senior clinicians. Now the interactions are between

whole ranges of clinicians, often at weekly intervals. They are starting to build closer relationships across sites as they get to know more about each other's strengths and areas of expertise. They are starting to build a trust that wasn't there previously. One junior clinician summed it up as "You get used to talking to them (in the education sessions) and build up a rapport. You gain a respect for their opinion". Another typical comment was "One of the values of the (inservice) sessions is that now we have no real hesitation to phone someone (for advice)". By expanding communication capabilities and increasing participation possibilities, the peripheries of the individual units have been made fuzzier and brought into closer relationship together.

There has also been a significant strengthening of collegial ties within other professional groupings, with *impacts far beyond the sites involved*. The nurse educators are a case in point. They all belonged to a state professional association, the Critical Care Nurse Educators Association (CCNEA), but did not know each other. The association had a once-a-year meeting for whoever was able to attend. A newsletter was sent out quarterly in-between times. This was a social world that had a couple of core people in executive positions closely engaged around the centre of the world, with the majority of members in relative isolation around a distant periphery.

After deciding to conduct education sessions across sites, the nurse educators from the three ICUs in this project started to meet together over the system to plan sessions. The meetings quickly evolved into far more general discussions and they soon realised how much practical and moral support they were deriving from each other. They discussed their experiences at the next annual meeting of the CCNEA, and also spoke of how they could see the association exploiting the technology. As a result of their enthusiasm, there is now a network of small groups of critical care nurse educators throughout the state who meet by fortnightly video-conferencing sessions. Processes are also in place to facilitate the flow of information between groups so that meeting outcomes can be shared as widely as possible.

As a result of extending communication and participation possibilities between ICUs, not only were the units brought into closer relationship but also the *internal boundary relationships* of a whole professional group have changed. People from the peripheries of the CCNEA are now in much closer relationship with the centre. By facilitating members' access to one another independent of geographical boundaries and by forming smaller centres within the larger group, the peripheries are in more synergistic relationships and educators are more closely engaging with one another. More generally, levels of commitment and participation in CCNEA have been significantly strengthened, hence strengthening CCNEA itself.

Evolving new consultation work practices

Thus the introduction of a new form of electronic communication, via video conferencing and data sharing capabilities, has had multiple boundary effects on multiple work practices: mediating the enlargement and enrichment of the intersection between the ICUs; making their peripheries more available to each other; and changing the relationship of work practices across space and time.

New consultation and transfer patterns are starting to emerge. Patients are being transferred more appropriately and best practice management is being instituted in a more timely fashion. A within-ICU effect is that more patients are now being cared for in the regional units with support from the tertiary centre. While this has resource and budget imposts, it also has positive out-

comes for local skill enhancement and family support structures. Many between-ICU effects have already been noted such as the increase in awareness of skills and knowledge across sites and a growth in trust and collegial networks resulting in a greater preparedness to call for help. People no longer call the tertiary centre by default for help but are now starting to call peers at other regional centres to draw on specific expertise. This is changing the very nature of the relationship between all the ICU worlds.

CASE 2: THE INTERNET EXPLORATION UNIT (IEU)

The Internet Exploration Unit (IEU) is a government-sponsored research project involving participants from government, industry and academia who are spread over three sites in different cities. The major participants and sites are drawn from the Future Generation Systems Centre (FGSC) and the Scientific Research Group (SRG). Their shared research area is how to deal with information resources on an internet-wide scale. The groups have access to advanced computing resources such as high-speed networks, video-conferencing and a range of computing hardware.

The study of IEU [4] took place over a nine-month period 2.5 years after it started. I had anticipated that the group would be negotiating more tightly coupled collaborations between sites during this time. This was because management had recently put out a directive that the members of IEU needed to move away from their predominantly site-based projects and be seen to develop closer working relationships. Ultimately, however, these closer cross-site and inter-organisation collaborations did not emerge.

In this case, I discuss the way in which electronic communication facilitated the initial emergence and evolution of this new social world, but at the same time was not a sufficient basis for drawing the component sub-worlds into more closely coupled relationships around the centre.

Supporting emergence of a new social world

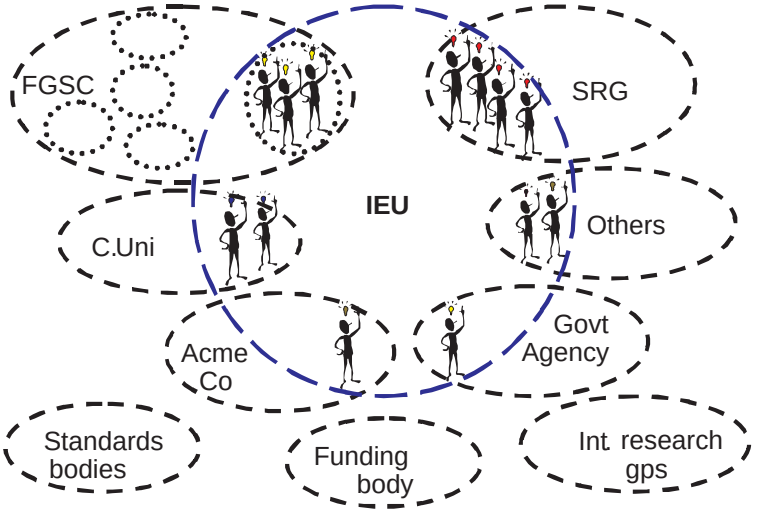
IEU can be characterised as a new social world that emerged from the intersection and merging of the peripheries of multiple other social worlds around a newly identified common purpose, i.e., to do research about Internet Exploration. This is illustrated in Figure 7.

IEU was formed, maintained and evolved primarily by means of electronic communication. Email, fax and telephone played a major role in facilitating the interaction across the different social worlds that led to its emergence. Now spread over three cities thousands of kilometers apart, the ongoing existence of IEU is enabled primarily by electronic communication in the form of email, mailing lists, shared web pages, file transfer facilities, telephone, fax, and so on. These forms of communication are especially important since the researchers who make up IEU have limited opportunities for face-to-face interactions across sites.

In principle, IEU core membership was to be relatively well defined since members were employed under the IEU budget. This provides the most publicly understood participation boundary. Over time however, they found that only certain types of interaction and thus levels of commitment to, and involvement in, the group were happening. The leaders of the two main sites, one associated with the FGSC, the other with the SRG, were most actively involved, i.e., working closest to the IEU centre and consequently to each other. The most common joint work was contributing to the writing of the annual report and fulfilling other reporting requirements related to their

shared funding source. Others in the group were drawn into these activities as required.

Figure 7. New IEU social world formed from the peripheries of other worlds



Otherwise, the work practices of the researchers within IEU evolved around independent site-specific research projects. In this way, the individual sites constituted strong internal sub-centres around the periphery of IEU. Relationships between the internal centres involved minimal administrative functions only.

Others even more peripheral to the activities of IEU included the executives of the participating organisations, standards bodies that IEU members contributed to, the funding body and the other people at each of the sites where IEU people worked.

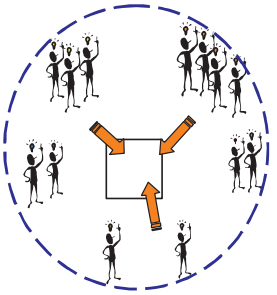
Changing the centre: when electronic communication is not enough

In the case of the nurse educators and the CCNEA, the emergence of multiple internal centres, through the networked small group meetings, served to strengthen the group as a whole and facilitated greater levels of commitment and involvement of members. In the case of IEU, the multiple strong internal centres served to weaken the shared IEU object of joint research and reduced it to an administrative function. This was against the spirit of the model under which the group had been funded.

It was for this reason the external management group gave the directive that the participating groups needed to be seen to be collaborating more closely. That is, the managers wanted the strong site-based centres around the peripheries of IEU to be in closer relationship to the centre and hence to each other, as depicted in Figure 8. By necessity, this would involve changing the nature of the IEU centre. The shared purpose of working in a common research area needed to be more explicitly articulated and concretely implemented as specific research outcomes rather than broadly shared interests. It would also mean changing the nature of the internal boundaries to become more open and permeable to facilitate increased interaction across them.

Significant effort was expended within the group to try to bring about this closer collaboration. They instituted weekly video-conferencing sessions between sites to facilitate more frequent and detailed discussions about their work. They held a full-day workshop at a neutral site where people discussed their various interests and tried to come up with a shared architecture model that would be used to position and relate people's work and interests.

Figure 8. Goal of directive: to refine object centre and bring researchers into closer proximity with the centre and each other



As a result of these activities, some cross-site interactions and collaborations did develop. Two of the researchers wrote a paper together. The prototype built by another researcher was used at a different site, requiring a lot of interaction, mostly via email, to properly install it. Most promisingly, another two researchers recognised that they were working on a very similar problem and decided to come up with a common abstract model of the problem domain. They spent a lot of time exchanging annotated documents via email, and talking on the phone. However, their work abruptly stopped when SRG executives decided to move their person away from IEU to another SRG project.

Ultimately, the evolution to a more detailed inter-dependent research agenda with consequent closer collaborations failed to emerge. This was despite active encouragement and the availability and use of all sorts of electronic communication, and potential access to any other state-of-the-art technology that might be required.

Some of the reasons for this failure were to do with the limitations of the technologies or the way in which they were used. One important factor was that the types of electronic communication used in IEU failed to provide opportunities for serendipitous interaction and relationship building that would normally happen with a co-located group, and out of which collaboration possibilities are often identified.

This is in line with the findings from Kraut and Egido (1988) that physical proximity increases the likelihood of informal communication, that is higher quality and lower cost than more distributed cases, which in turn increases the likelihood for common interests to be identified and collaborations to emerge. Video conferencing technology can be used to facilitate open media spaces promoting informal interaction (e.g., see Adler and Henderson, 1994) but it was not used in this way by IEU. They used video conferencing as a stand-alone system independent of their normal working environments; the meetings conducted over the system were relatively formal and structured. Thus, their use of electronic communication was *unable to overcome some of*

the problems of distributed physical boundaries and their strong relationship to the work practice boundaries.

Most of the reasons for failure, however, were organisational and cultural. While it was true that each of the researchers was a member of the IEU social world, each was also a member of their separate organisations. The site-based centres within IEU reflected the participant organisations. These organisations were very different. In particular FGSC and SRG were direct competitors in many other areas in the market place, while at the same time having a joint agreement about IEU. They offered their employees different reward structures.

SRG employed people first and foremost on the basis of their individual skills and interests. Commercial activities were encouraged over research: if a consulting opportunity arose, personnel would be diverted away from their IEU work, against the terms of their agreement with the group. The SRG members of IEU knew that if IEU folded for any reason, they would be moved to another project. The IEU members from FGSC, on the other hand, were employed to specifically work in IEU and were expected to form a relatively stable research group with synergistic interests. The future of their jobs at FGSC relied on the success of IEU. If commercial activities were undertaken, they were done so in the name of the IEU group, and income and kudos were attributed to the IEU, not diverted from it.

These *competing organisational centres and associated work practices* fostered very different levels of commitment to IEU goals. This was reflected in the energy and time that different people put into trying to evolve closer collaborations. Ultimately, the competitive site-based centres remained strong around the periphery of IEU. The interactions between sites remained largely administrative, or around relatively well-defined chunks of information as embodied in a document or a completed prototype.

In summary, electronic communication was not enough in IEU to overcome the contradictions between physical distribution and dislocation, competing organisational cultures, and the need to evolve closer collaborative relationships within the IEU world. Hence, even though electronic communication was the catalyst for the emergence of the new IEU social world by extending the functional bounds of effective communication, it was not sufficient in its own right to mediate change in the definition of the centre and the internal proximity relationships. Nor was it sufficient to foster greater levels of commitment and participation.

CASE 3: DIGITAL RADIOGRAPHY

Still in progress, the Radiology Department of the Major City Hospital (MCH) is involved in a project to digitise their radiographic procedures. Traditionally, a doctor writes out a standard request slip for a radiograph, or x-ray as it is commonly called, the slip is sent to the Radiology Department, and the patient is either brought to the department or a mobile unit is taken to the patient, where a radiographer takes the x-ray. A large plastic film of the x-ray is produced and a consultant radiologist writes a diagnostic report. Both x-ray and report are then sent back to the requesting doctor on the ward where the doctor can view the x-ray via the wall-mounted light box, or in fact via any white light source. The advantages of this process are that the x-ray is relatively portable and versatile, and anyone with access to a light source (and appropriate authorisation of course) can view the films.

There are also disadvantages, with varying impacts on patient care. Significant time delays can occur when request slips and hard-copy films have to be carried by courier around the hospital complex. Films can be misplaced. Reports can be delayed. The film can only be viewed in one place at the one time. The interaction between the radiologist and the ward doctor is mostly indirect, mediated by the request slip and the report. The radiologist sometimes makes a diagnosis with incomplete information about the patient's condition.

The goal of the current project is to replace the hard-copy x-rays and reports with digitised images and reports. Also, as part of a larger computerisation project within the hospital, requests for x-rays are being submitted on-line. The new computer system is expected to overcome many of the limitations of the old system, and provide more timely production of x-rays and reports, earlier institution of appropriate management, more secure and reliable access to patient data, and simultaneous access from many places at once. Consequently, the project entails significant changes in the technology and processes of the Radiology Department.

Extending the influence of the Radiology Department

In the case of the Radiology Department and its move to a digital imaging system, we can already anticipate some of the potential boundary effects – both for the social world of people concerned with a patient's x-ray, and for the broader hospital social world of which the Radiology Department can be considered a sub-world.

Changing the nature of internal group boundaries

The decision to implement a digital radiography system will enable new forms of communication within the social world of people who have an interest in the same x-ray and/or patient. The shared goal of caring for that patient constitutes a centre for this world. The nursing staff and doctors involved in the direct care of the patient are the core persistent members of the world. Others, such as the staff from the Radiology Department, are drawn from the periphery towards the centre of the world for a period of time, usually on specific request for specific activities.

New forms of communication via electronic orders, digital x-rays and on-line reports will change the nature of the work practice boundaries within this social world. They will *shorten the cycles and phases of interaction* around the request and receipt of x-rays, i.e., changing the temporal boundaries of the world.

Together with other communication infrastructure being installed, a digitised radiology system will also change the physical constraints on who can be involved in the social world. This is because the limit of effective *communication has been extended* in terms of both bandwidth and accessibility. Participation will no longer be constrained by physical boundaries; the radiologist can be located anywhere, even in another country, so long as she/he has network access to the digitised image.

Direct interactions between the specialist radiologist and the requesting doctor on the ward will also be more likely when they can both view the same image, share annotations, and discuss the patient's case over the system. In this way, the radiologist can be drawn in as required from the peripheries of the world into closer relationship to the centre, even if only for a short period of time.

Changing artefact border resources

The border resources of the x-ray as an artefact mediating the work practices will also change. The hard-copy nature of the image and report, constraining use to one place at one time, currently functions as a border resource that promotes patterning of use and facilitates variable participation within the world. During the morning ward round, for example, the team of clinicians looking after a group of patients would go to the light box to view a patient's x-rays, then move to examine the patient at the bedside. The physiotherapist might return to the x-rays after the round to determine his/her treatment in more detail. The medical students might return at yet a later time to review the films from an educational point of view. Because activities around the artefact are physically located in 'public' ward spaces, the very fact of its use, for example in a ward round, is publicly available for anyone who needs to know. Thus, the movement of the hard-copy x-ray across departments, and then its location and use at any point in time, help mediate and pattern interactional phases and promote public availability of actions within the world.

When digitisation comes into effect, the x-ray artefact will have far *less of a role as a public marker of social world participation*. The patterns and phases of interaction around it will be more blurred and potentially overlapping since the image can be accessed simultaneously by different people from different network locations for different purposes. Further, these interactions will not be directly or publicly available to others because they will happen in a digital space and not in a physical space.

On the other hand, a digitised system should promote much *richer media of communication*, especially in the context of the general technical infrastructure being installed in the hospital. Direct interactions between the specialist radiologist and the requesting doctor on the ward will be more likely because neither will have to walk across the hospital campus to see the other – they can both view the same image, share annotations, and discuss the patient's case over the system.

Changing inter-world relationship boundaries

Another way of looking at the Radiology Department, and indeed all the other departments and wards in the hospital, is as separate sub-worlds of the larger hospital world in which they operate. Each ward and department has its specific role to play. The Radiology Department provides x-ray services to the hospital, the medical ward looks after patients with medical conditions, and so on. This reflects an organisational structure within the hospital based on semi-autonomous vertical departments that have their own allocated budgets and are expected to function as independent cost centres.

The operational relationships between the wards and departments are relatively well defined, having evolved and stabilised over many years of operation. In particular, the Radiology Department has very simple and narrowly defined points of interaction with the wards for service request and delivery. These interfaces are mediated by discrete standardised artefacts creating transparent communication pathways, where the x-ray request slips come into the department from the ward, and the hard-copy x-ray and report are later sent back to the ward.

We can talk of the peripheries of the department and the ward as being relatively fixed and impermeable except at defined interface points – in short being well bounded and distinct. This is congruent with a semi-autonomous 'vertical' organisational structure.

The digitisation of the Radiology Department radically changes these relationships in ways that are unsupported by the organisational structure. Previously, any changes by the Radiology Department were usually contained within the department with minimal impact on the other wards and the interface mechanisms. The department could choose to change all of its internal processes or the supplier of its film material, etc. but as long as the ward clinicians could read the x-ray on their cheap wall-mounted light box, it was of little consequence to them.

With digitised images, the wards now need a specially configured terminal to access and view the images. Further, the committee looking after the digitisation project has determined that, for security and privacy reasons (justified or not), this terminal cannot be used for any other purposes. Because these terminals are considered a ward acquisition, the wards are expected to fund the terminals from their own cost-centre budgets and there is no funding support from the digitisation project. They also have to find space for them at already over-crowded nursing stations.

As such, the introduction of digitised images as a new form of electronic communication between the Radiology Department and the wards creates complicated horizontal dependencies between hospital sub worlds that hadn't previously existed – *the operational peripheries of the worlds are brought into overlapping relationships*. This sets up a *contradiction* within the hospital system: the horizontal dependencies have significant cost and space implications but they are not supported organisationally by a structure still based on semi-autonomous vertical departments functioning as independent cost centres with well-defined service request-delivery interface relationships.

A more potentially far-reaching impact of digital radiography is the education of medical students. Previously, the Medical School social world was thought to be quite distant from the Radiology Department because they were only indirectly involved in the department's output and belonged under the university hierarchy not the hospital hierarchy. While some teaching sessions are scheduled, there are many informal ad-hoc sessions that take advantage of the moment to provide a valuable teaching opportunity. X-rays are an important teaching tool in this regard. It is not uncommon to see a senior doctor showing a group of medical students an interesting x-ray they think will be instructive. This can happen because minimal space and equipment are required; the 'teacher' can pick up the film and take it to a small room attached to the ward that has a light box. They can even use the corridor and a ceiling light to show the students.

Now the Medical School finds that it too is being brought into an operational relationship with the Radiology Department, asked to provide expensive high-end equipment in order to access digital images as teaching resources. It is unlikely to be able to provide such spaces on every ward as it now does with the light box in the attached room. Because of the costs involved, they expect they will only be able to fund a few terminals, that will then need to be used in larger spaces by larger groups to ensure equitable access – more centralised teaching in larger group auditoriums is a likely outcome.

Ad hoc access will also be hampered because the committee wants to institute strict request procedures for teaching requirements that will require days of advanced planning. Hence timely

teaching opportunities are less likely to happen for access reasons as well as for space and equipment reasons. In this case, the introduction of a new form of electronic communication could serve to formalise and complicate a boundary between the Medical School and the teaching hospital where previously it had been relatively informal, flexible and permeable. The work practice of teaching students is also likely to become more formalised.

In summary then, electronic communication has complicated and made more explicit the relationships across boundaries that were simple and/or relatively implicit within and across organisational structures. Peripheries of departmental, ward, and medical school centres that were previously distinct and distant are now brought into closer relationship. It could even be argued that they form the beginnings of a new social world defined by "those needing to avail of Radiology services". This is a social world that requires a commitment of money, space and resources but it is not supported within current organisational structures. The challenge will be to find new organisational structures that are able to deal with the new forms of inter-centre relationships facilitated by electronic communication.

BOUNDARY EFFECTS OF ELECTRONIC COMMUNICATION

In many previous discussions about boundaries, the focus has largely been on external boundary forms or boundary artefacts. While some discussions have referred to the underlying social boundaries that these boundary forms reflect and support, exploration of the social boundaries *per se* has not been the focus of the work. I argue that a focus on the external boundary form can sometimes lead to 'boundary as edge condition' being the dominant boundary metaphor that implicitly underlies our use of the term boundary, even if we are talking about socially situated and sustained boundaries.

Strauss suggests that "perhaps it would be better to discard the concept ... of boundaries and substitute something like peripheries" to avoid arousing such irrelevant imagery and to instead capture the variation and fluidity of social world boundaries. The *framing question* for this paper became: where would it take us if we were to use the concept of 'boundaries as peripheries' rather than 'boundaries as edges' for talking about work practices and the effects of electronic communication?

In this chapter, I have sought to complement the focus on external boundary forms and mediating artefacts with a focus on work practice boundaries, drawing on concepts from both Strauss' Theory of Action and from Activity Theory. Work practice boundaries are seen as constituted in the situated actions of members of a social world sharing some commitment to collective action, or in Activity Theory terms, of subjects in a community sharing a common object. These fluid social world boundaries are far more accurately characterised by a metaphor of centres and peripheries than edge conditions. The effect of edge boundaries can still be evident, but this is given by degrees and limits of communication, participation and commitment as peripheries in dynamic relationship to the centre.

Given this characterisation of work practice boundaries, the case study vignettes in the previous sections provide a starting point to explore the various transformational effects of electronic communication in mediating work practice boundaries and boundary crossing.

The boundary effects of electronic communication become as rich and varied as the boundaries themselves.

In the following discussion, I summarise these effects in terms of within-world centre-periphery relationships, between-world relationships, and relationships with other boundary forms. These are not meant as categorical characterisations of the boundary effects. Nor is it useful to wonder whether something is a within or between effect. It is whatever makes most sense from the perspective of interest. For example, the ICU telehealth consultation could alternatively be described as a boundary-crossing activity between the individual units as centres, or as an example of Engeström's knotworking (1999) rather than a transient social world.

The purpose of trying to summarise the boundary effects here is to start to define a richer language for talking about crossing work practice boundaries – not as a breaching or crossing over, being in or out but as something that reflects the fluidity and complexity of socially situated boundaries.

Internal centre-periphery relationships

Electronic communication can change the internal relationships of the social world peripheries to the centre in a number of ways.

By extending the limit of effective communication, the reach of the periphery of the social world can be extended to include people who were previously unable to interact with the social world. The radiologist who can now report on x-rays from a remote site is a case in point.

Internal peripheries can be moved into closer relationship with the centre. This was the case when more of the ICU staff could become directly involved in the telehealth consultation using video-conferencing technologies. In the case of the CCNEA, there was a dramatic change in the level of commitment and involvement that the nurse educators could have with the group. A further effect was a refining and strengthening of the core role of the group as the centre around which they interacted.

Electronic communication can also constrain or define the types of relationships that can be most effectively carried out with the centre. In the IEU case, the forms of electronic communication selected, and the way in which they were used, were not conducive to the ad hoc interactions necessary for the emergence of a more refined object and consequent new collaborations. They tended to reinforce interaction at a formal management level, and by default, allowed the site-based sub-worlds to strengthen as a focus for work and the IEU centre to be weakened. By contrast, the video-conferencing technologies used by the members of the CCNEA supported the emergence of strong sub-worlds, which in turn served to strengthen the CCNEA centre.

Boundary crossing from the perspective of the internal centre is concerned with the relationships between the various peripheries around the centre. For example, we can talk about the way in which electronic communication was used to mediate the interactions between the management group and the different site-based researcher groups within IEU.

Between-centre relationships

Electronic communication can also change the relationships between different social world centres.

It can facilitate the merging and intersecting of previously distinct social world peripheries. It can change the nature of the interfaces between social worlds, and hence the permeability, visibility and accessibility of different worlds to one another, as well as the scope of influence from one to the other. This was particularly so with the Radiology Department and the Medical School, whose peripheries were brought into much closer and dependent relationship by the digitisation project. At the same time, the boundaries were also made more impermeable because it was harder for the Medical School teachers to interact with radiological data.

New social world centres can sometimes form out of the merging and intersecting of different social world peripheries. IEU, for example, evolved after the participating organisations recognised that their synergistic research interests could be strong enough to form a new centre as a Research Project. In this case, the peripheries of the new IEU and the participating organisations remained overlapping. In other cases, it could be expected that the peripheries of the original worlds might become so distant as to form a distinct social world.

Electronic communication can change the nature of the boundary objects that mediate the interactions between the worlds, which in turn can change the nature of the work practices around that object. This was the case when the x-ray moved from being a hard-copy artefact to a digitised artefact.

Relationship between work practice boundaries and other boundary forms

Work practice boundaries do not exist in isolation but in the context of, and mediated by, multiple other boundary forms – spatial, temporal, organisational, and so on. These different boundary forms mutually shape and evolve the other. Continuing use of the centre-periphery metaphor, we can talk of the different centres and their peripheries being in synergistic or congruent relationships, or not, as the case may be [5].

In the ICU telehealth project, electronic communication changed the relationship of the work practice boundaries with spatial and temporal boundaries in a way that was congruent with the goals of the centre – accessing expertise to provide optimum patient care. The temporal boundaries of consultation, data sharing, and management suggestions that might sometimes take days can now be compressed within the span of a single video-conference session with application sharing capabilities in a matter of minutes.

In IEU, the goals of the social world centre were in direct conflict with the goals of the participating organisational centres. These conflicts had always existed but now the electronic communication that enabled IEU to emerge in the first place also enabled these conflicts to be brought into sharp and explicit focus. There might have been some intersection of the peripheries of the organisations but not of their centres. Another factor in the failure of IEU to evolve closer collaborations was the lack of congruence with a strong spatial centre, physical or virtual. The fact that the strongest collaborations (work practice centres) happened within sites that had relatively synergistic relatationships among spatial centres, organisational centres and sub-world centres, is a telling point.

The digitisation of radiographical images as a new form of electronic communication created horizontal boundary effects between departments and wards that were incongruent with the ver-

tical organisational structure and funding arrangements within the hospital. Even more so, it changed the relationship of activities around the x-ray as an artefact, and the temporal and spatial boundaries of its use. Some of these are congruent with the core goal of providing effective patient care, e.g., by facilitating multiple simultaneous accesses. But for the medical school, it decreases the likelihood of small groups being able to take advantage of teaching opportunities as they arise because images now have to be booked far in advance, and specialised equipment and locations are required.

DESIGNING FOR CENTRES AND PERIPHERIES

The relationships of social world centres and their peripheries, both within and between centres, and the relationship of work practice boundaries to other boundary forms are defined in multiple, complex, and dynamic ways. They are not boundaries in the form of relatively stable edges to be breached or bridged by means of electronic communication as a single simple effect. The very act of deploying any form of electronic communication changes the nature of the boundary and its internal and external centre-periphery relationships in a whole variety of ways, as well as its relationship to multiple other boundary forms.

In designing support for social worlds through electronic communication, we need to make an explicit choice about the boundary metaphor that motivates the design solution. Previously, many social world boundaries have been strongly congruent with spatial boundaries and so it was not inappropriate that a physical boundary formed the basis of the design metaphor. The clinicians who form the ICU social world, for example, work in the one physical ward space in the hospital. Sometimes though, these strong identifications with spatial centres can blind us to the richness and complexity of the social world with its different degrees and limits of communication, participation and commitment. Using a 'boundary as edge condition' metaphor in design reinforces this blindness.

A 'boundary as periphery-centre relationship' metaphor motivates the design choices by a notion of boundary that is socially situated and dynamic, not physically situated and fixed, even though 'boundary as periphery' might be physically mediated. It also motivates consideration of multiple different periphery relationships with the centre along multiple dimensions. For example, how can the different levels of participation and engagement within the ICU social world be supported, e.g., the nurses who provide one-on-one care, the doctors who look after a group of patients, the ancillary services who interact with all the patients at different times for specific activities, and the families of the patients who also participate in their loved one's care? How can increased levels of commitment be encouraged from all IEU members? Can the temporal boundaries of the telehealth consultation be even further extended to support closer ongoing management of a patient at a remote site?

In designing support for social worlds, we also need to take more explicit account of the transformational boundary processes that are facilitated by the design solution, e.g., how the boundaries will be evolved as a result of electronic communication and how the proximity relationships with other boundaries, internal or external will be impacted upon.

Further, and perhaps most importantly, we need to consider the relationship of the work practice boundary to other boundary forms and look at the congruence of the work practice boundary ef-

fects with these other boundaries. If, for example, the introduction of electronic communication was to have any impact on facilitating more closely coupled collaborations within the IEU group, the way in which the spatial and organisational boundaries support or fail to support the work practice boundaries would need to be explicitly addressed.

CONCLUSION

What do we gain by thinking about work-practice boundaries as centres and peripheries in dynamic proximity relationships, rather than as stable edge conditions? The case studies discussed here suggest the following:

- a primary focus on people and practice as social worlds/communities
- an understanding of the systems and artefacts that mediate their work from the perspective of the practice
- a way to make visible and explicit the richness and variety of socially-situated boundaries, both internal and external
- and consideration of the processes and work practice effects that can happen by virtue of crossing boundaries by means of electronic communication.

Specifically, the focus of the thinking is on the nature of the work practice, with respect to the object shared by the community or social world, and as supported by the spaces, artefacts and other boundary forms that enable or constrain those interactions. Spaces and artefacts reflect or shape just some of the group's own work practice boundaries. For example, just because a group works in a physical environment that controls who can access the space, it does not necessarily follow that the physical boundary strictly reflects *the* work practice boundary of the group. Room access control can be interpreted as supporting one level of engagement, but it is not the only one. The work practice boundaries are far more variable, permeable and dynamic than the external form implies.

With a centre-periphery approach, we can still get the effect of a stable edge condition when a periphery is well defined – this might be synonymous with a physical boundary. But we are also invited to explore the multiple other ways that levels of participation, communication and commitment are continually being mediated and evolved by the group. Not all of these peripheries will have the same external forms of support. Virtual environments and software artefacts now give us the possibility of providing far more flexible forms of boundary support than have previously been possible with physical structures and artefacts.

Thinking in terms of centres and peripheries also draws attention to the rich variety of peripheries as boundaries *within* a work practice as well as those between work practices. In fact, the distinction between what is internal and what is external is often blurred. Further, we are invited to understand the complex interplay between these work practice boundaries and other types of boundary such as spatial, organisational, and so on, that mutually shape and transform the other. Effective work interactions require all these boundaries to be synergistically aligned to some degree.

In summary, I have argued that work-practice boundaries are better characterised as centres and peripheries. Otherwise, we can unintentionally use the term boundary as implying stable edge conditions, or assume that an externalized boundary form is synonymous with the work

practice form. The extent to which we take on this implicit notion of boundary as edge however is the extent to which we miss the subtle and not so subtle shades and variations in work-practice boundaries; it is also the extent to which we render invisible and unproblematic the very nature of the boundary itself and the effect that electronic communication can have. This is not to reject the affordances that can be supported by using an edge metaphor, e.g., security, privacy, identity, separation, control, hiding unnecessary detail, etc. Rather it is saying that the metaphor is not rich enough to capture the dynamic and fluid character of social boundaries or, consequently, the ways in which electronic communication can change or evolve these boundaries. A centre-periphery approach can account for these 'edge' affordances and more.

The transformational effects of boundary crossing using electronic communication thus need to be more explicitly acknowledged and understood, rather than implied as unproblematic. As seen in the case study vignettes, we can characterise boundary crossing effects as, for example, extending the social world periphery, or changing the proximity relationships to the centre, or facilitating the emergence of new centres, or changing the relationship between centres, e.g., to intersect, merge, strengthen, weaken, and so on. Thus electronic communication can change the very nature of boundaries and work-practices – sometimes in unanticipated ways, sometimes enabling whole new practices to evolve, sometimes in ways that create discontinuities between the formal conceptualisation of work practices and the reality of the transformed work practices.

The challenge is to find ways to incorporate such boundary notions into the systems and artefacts we design to support work practices, and to focus as much on the dynamic social boundaries we seek to support as on the external enactment of some boundary form or artefact.

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Notes

[1] The term 'electronic communication' is used here in its broadest sense to mean any form of direct or indirect communication support.

[2] As is usual with the reporting of such studies, all proper and organizational names are pseudonyms.

[3] Fuller descriptions of the telehealth project can be found in Fitzpatrick (1998) and Kaplan and Fitzpatrick (1997).

[4] The IEU study is discussed more fully in Fitzpatrick (1998) and Fitzpatrick et al. (1998).

[5] In "Centers of Collaborative Work" by Kaplan et al (1998), we explore some of these themes,

but use a notion of centres drawn from Alexander (1993) and Gamma et al (1995). This is different to how 'centres' is used in this paper.

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