Temporal boundaries to knowing and learning in integrated product-service organizations

Jon E Lervik[1, 2]
j.lervik@lancaster.ac.uk

Kathryn M Fahy[1]
k.fahy@lancaster.ac.uk

Mark Easterby-Smith[1]
m.easterby-smith@lancaster.ac.uk

Carole Elliott[1]
c.j.elliott@lancaster.ac.uk

[1]Lancaster University Management School, Bailrigg, Lancaster LA1 4YX, Great Britain

[2]Norwegian School of Management BI, N-0442 Oslo, Norway

ABSTRACT

Situated learning-approaches in organization studies have developed from studying well-bounded communities to addressing the role of boundaries to knowing, such as boundaries between occupational communities, organizational boundaries, geography, and the material and spatial context of learning. The literature has been relatively oblivious to time and temporal structuring as central aspects of organizing, and as we will show, with clear implications for opportunities for learning and sharing knowledge within organizations.

We examine temporal boundaries in a class of organizations where interdependencies over time are central. Product-Service systems entail delivery of a product followed by a trail of service, upgrade and maintenance activities over the lifecycle of the system. We show how knowing and learning across product-service system organizations is hampered by different types of temporal boundaries.

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INTRODUCTION

The notion of boundaries is a hot topic in recent advances in situated knowing and organizational learning theories. However, boundaries are mainly conceptualized in spatial or topological terms, such as geography, organizational boundaries, social networks and structural holes. In this paper we want to draw more attention to time, temporal boundaries, and its implications for knowledge management and organizational learning. Engeström (2006) cogently articulated how situated activity is not well bounded, but extends in time and space.

Situated activity is always situated in time and space. In this paper we argue that the situatedness *in time* is as important to look at and analyse as activities situated in space. Temporal situatedness can be a source of knowledge stickiness. However, we do not argue temporal boundaries should take precedence and replace spatial boundaries. What we do argue is that many empirical that are currently dissected using analytical tools from a spatial vocabulary can be reframed and new insights can be had using a temporal analytical framework.

Consider for example the "boundary problem" in collaborative research between academics and practitioners (Van de Ven & Johnson, 2006). Discourses about sources of tension or knowledge stickiness can revolve around actors from the two sectors being embedded in different institutional structures with different incentives (bottom line vs. publications), engaging in different types of language games. Other dichotomies include the tension between basic vs. applied research, practical vs. theoretical etc. These partial diagnoses all contribute to our understanding of boundary problems. To this we can add actors' different temporal orientations (Clark, 1985), in terms of the pace of individual career clocks, the frequency of organizational performance measurements etc. The different temporal orientations contribute to the tension of aligning and collaborating in academic practitioner research, for examples in negotiating project plans and sequencing of output. It is not meant to substitute the earlier insights, but can provide additional and sometimes crucial insights.

The objective of the paper is to draw attention to a gap, and to develop a vocabulary that allows us to grasp and analyse time and temporal boundaries to knowing. We develop our argument with reference to examples of temporal boundaries in four organizations delivering product service systems.

The paper is structured as follows. In the next section we briefly review the literature on situated learning, communities and knowledge boundaries. We point to a gap concerning activity also being situated in time, and having temporal interdependencies. In the third part we introduce a vocabulary and a "grammar" that provide the tools for capturing and analysing temporal aspects and its implications of learning and knowing. In the fourth part of the paper we illustrate the value of a temporal lens with analysis of temporal boundaries in p4 companies that offer product-service systems.

SITUATED LEARNING AND BOUNDARIES

Classical contributions within organization studies focussed on well-bounded collectives, for example Orr's (1996) ethnography of Xerox photocopier repairmen, Yanow's study of expert flute makers (Cook & Yanow, 1993), and Schon's (1983) account of reflexive practitioners in various professions . Interaction and interdependencies across communities were downplayed or not addressed in these classic studies.

Spatial boundaries between knowledge communities

Lee and Roth (2003) point out that today's communities are more likely to be "patchwork" entities in which "shifting relations, contexts, and alliances are a more prominent feature of the work environment" (p. 122). Lindkvist (2005) suggest the term knowledge collectivities to refer to collectives with limited time span, multiple and shifting membership of members from different knowledge domains.

The notion of boundaries has become a central concept – especially in studies of new product development activities (Carlile, 2002; Dougherty, 1992; von Hippel et al., 1995), activities with high intensity and pacing that require inputs and collaboration from experts from several disciplines. Studies address the challenges in learning and coordination across "communities of knowing" or occupational communities (Bechky, 2003; Boland & Tenkasi, 1995). These studies have emphasized the stickiness and situated nature of knowledge, and limitations to transferability across boundaries.

There is also a body of research starting from a more objectivist view of knowledge that have examined other types of boundaries to knowledge, such as boundaries between organizations and subunits within organizations (Gupta & Govindarajan, 2000; Szulanski, 1996), the impact of geographical separation (Hansen & Løvås, 2004), and national boundaries in terms of cultural or institutional differences (Björkman & Lervik, 2007; Hong, Easterby-Smith, & Snell, 2006; Kostova & Roth, 2002). What these literatures share is highlighting spatial boundaries while leaving temporal boundaries in the dark.

Expansion of objects in space and time

Engeström gives a counter-intuitive, yet convincing argument against the dominant discourse of globalization and time-space compression. It is quite common to read management articles which starts with rehashing the impact of falling transportation costs and "death of distance", the revolution in information and communication technologies, with instant information available at your fingertips. Engeström tells a different story, and accounts how distance is very much alive, and so is time.

Engeström is a central proponent of activity theory, which is one of the dominant "schools" in organization studies of situated learning (Blackler, Crump, & McDonald, 2000; Nicolini, Gherardi, & Yanow, 2003). The object of activity is a central concept in activity theory, the object on which work is done, attention is directed towards. Engeström, Puonti and Seppanen (2003) argues we need methods and approaches to do research and interventions on "expanding objects of activity". Problem solving is rarely an activity that is well bounded in time and space, but is rather enmeshed in a network of connections and interdependencies to other locations and to historical and future events. He discusses the example of police investigations of economic crimes, where police work (and subsequently sociological studies of police work) had to change their basic conception of an act of crime. An act of crime is conventionally understood as a well bounded event, e.g. a person was robbed at *a specific time and place*. Not so for economic crime. Transactions involve several locations, often offshore banks, and "the crime" is often a flow or cycle of activities over longer time spans. This required rethinking of police work. Engeström is to our knowledge one of the few practice theorists that has explicitly addressed time as a concept or variable to take into account.

Examining learning across spatial and temporal boundaries

One example of research that has treated spatial and temporal boundaries in a symmetrical way, is Epple and Argote's research on learning curves. The general theory of learning curves state that productivity increases over time as actors gain experience, demonstrated in e.g. the costs of aircraft production (Wright, 1936). Argote and Epple (1990) demonstrated different rates of performance improvement (~learning) stemming from knowledge transfer across product groups and organizations. Another study (Epple, Argote, & Devadas, 1991) examined intra-plant transfer of efficiency gains in a manufacturing plant with a two-shift cycle. This is one spatial setting with the same equipment and the same production process. The plant was started with one shift, and the second shift was introduced several months later. There was a substantial but not complete transfer from one shift to the other, as indicated by the second shift's performance gains closing the gap to the first. The first shift's experience to some extent influenced the performance of the second shift, as experience was embedded in the plant equipment. This could be things like fine-tuning of equipment parameters and tolerances from which also the second shift would benefit. The "hardware" was thus a boundary object that embodied knowledge and affected the performance of the second shift. Whether the members of the second shift "learnt" in a cognitive sense is a different question. This example is useful to illustrate that we can conceptualize and analyse temporal boundaries in a way akin to current work on spatial boundaries.

A TEMPORAL LENS ON BOUNDARIES TO KNOWING

In this section we conduct a brief review of the broader literature taking a temporal lens in organization studies. We furthermore discuss the relevance and impact on organizational learning and knowledge management.

First we need to introduce a basic vocabulary for talking about time, and then we review how temporal aspects interact with knowing and learning in a so-called "well-bounded" setting. In the third section we outline the types of temporal boundaries in complex organizations, and how temporal boundaries affect knowing and learning.

Vocabulary for exploring temporal boundaries

The 'natural' conception of time is clock time, as a linear continuum – "infinitely divisible into objective, quantifiable units [that are] homogeneous, uniform, regular, precise, deterministic and measurable"(Ancona, Okhuysen, & Perlow, 2001b: 514). Although the unit of one second today is defined with reference to 'nature' – the radiation frequency of caesium atoms – clock time is very much socially constructed. The conception of time – especially that of workers – as a resource or a commodity that can be managed, bought and sold, measured and monitored, was important to the industrial revolution.

Ancona et al. (2001b) identify five different conceptions of time, including clock time, cyclical time (four seasons of the year), life cycles (stages of progression from life to death of individuals, teams, organizations) and event time, which can be predictable (the timing of Easter, guided by the lunar calendar) or unpredictable (the irregular reoccurrence of earthquakes). We draw on all these conceptions in everyday life. For example these conceptions of time guide our entrance and exit from the labour market (biological life cycle), planning our journey to work (clock time), how we refer to activities ("it was built after the last earthquake"), or taking holidays (event time, clock time).

Temporal aspects affecting knowing and learning

To anchor our review and highlight the implications for knowing and learning, we discuss this in relation to generic examples around project work. Projects are central organizing devices in today's economy, as a vehicle for coordinating activity and aligning efforts towards specific goals, with a limited duration. For simplicity's sake, we consider one recurrent type of project organization, where projects are internal to an organization, as temporal units with personnel allocated from 'home base' disciplines. Further we assume individuals are assigned to projects full time. We can now consider how temporal variables influence knowing and learning within a project based organization.

Project duration

When a project has a longer duration beyond a certain not to distant time horizon, the nature of a project changes qualitatively. Sydow, Lindkvist and DeFillippi (2004) argues that

> [P]rojects with a duration of 10 to 15 years, not uncommon within the military and pharmaceutical industries, should give rise to knowledge/learning features which are not very different from those of permanent organizations. (p. 1480)

When project have long durations relative to individuals' career life cycles, it changes the opportunities of knowing and learning through several mechanisms. The project becomes the locus of identity. If team members develop emotional ties, loyalties and commitment, the locus of this is the project rather than the organization. (The lack of) shared identity reduce knowledge sharing, and reduce willingness to engage with and test out unproven knowledge from other subunits (Kane, Argote, & Levine, 2005). Furthermore, long-lasting formal project structure alters the structure of social networks. Social ties outside the project are not evoked and may decay. Project members interact mostly with other project members. They may have fewer and weaker ties with disciplinary colleagues in other parts of the organization. This reduce opportunities for knowledge exchange and interaction across projects (Nahapiet & Ghoshal, 1998). Lack of social ties and shared knowledge also affects relational trust (Tsai & Ghoshal, 1998), further limiting opportunities for knowledge sharing.

Pacing of activities

A recognizable pattern in most projects is an increasing pace of activities when milestones and deadlines are approaching. Implications for knowledge management are most acute towards the end of a project. As the pace increases towards the end of a project, members keep an eye on their deliverables, and are even more hesitant to invest in knowledge management activities or assisting others. Also, when the project is delivered, individuals are rapidly dispersed to their respective home bases or new projects. Thus, important opportunities for collective inquiry and reflection – a kind of "after-action review" (Popper & Lipshitz, 1998) – might be lost.

Liminal time between projects

Wenger (2003) highlight the positive role of a (temporal) space to breathe and catch up between projects. This is also the idealized model of many organizations, with liminal time to catch on technical developments within the field, to take a course or liaise with other colleagues. However, external temporal patterns may take priority over individual needs.

Client requests, accounting systems and project managers may have more legitimate claims on individuals' time than "nice to have" knowledge exchange and competence development.

Conceptions of time as a scarce asset

> A recurring tension within project-based organizations appears to be between the immediate task and performance demands of the project at hand versus the opportunities for learning and disseminating project practices that can be employed in subsequent projects. (Sydow et al., 2004: 1476)

The commoditization of time, and how organizations measure and assign cost to time has also major implications for knowledge sharing. The accounting systems of time costing and monitoring time use and allocate cost to various project activities, means there are strong disincentives for helping others.

The notion of time as a "scarce resource" is highly institutionalized and taken for granted in modern capitalist economies. This manifests itself in organizations both as formal structures and mechanisms for monitoring and control, as well as internalized mental models of "time is money". Taken together it becomes a strong temporal structure that guides and informs everyday activity.

Time as a scarce resource is probably the conception of time that is most frequently evoked in discourses on "conventional wisdom" in KM; that people don't have time "to do KM". With accelerating competition and change, people focus on their day jobs, and don't sit down and document their activities for posterity, for the benefit of a database or an unknown recipient.

Summary

These factors suggest that time deserves focus in scholarly research, and is important in organization design. The individuals' cycles of project related work, the duration in each project, and duration between projects are important aspects of organization design that shapes opportunities for learning and knowledge exchange in organizations.

However, these initial reflections on the role of time do not really engage with the notion of learning as spatially and temporally situated. In the next section, we explore the notion of different types of temporal boundaries to knowing and learning in complex organizations.

Tmporal boundaries and entrainment

We introduce the notion of temporal boundaries to refer to challenges of entrainment or temporal alignment between actors or activities. We define temporal boundaries as "*the lack of alignment of time orientations of actors or lack of entrainment of activities in one unit to those of another unit*". The first aspect concerns boundary issues emanating from actors with different attitudes towards time or time orientations. The example of academic-practitioner collaboration in the introduction is one example. The second aspect concerns the (lack of) entrainment (Ancona & Chong, 1996) of interdependent activities with different pace, rhythm of time cycles, for example when the marketing department launches a marketing campaign for a new product, whereas the sales department has not been able to get the products into stores yet.

Entrainment is defined as "the adjustment of the pace or cycle of one activity to match or synchronize with that of another" (Ancona et al., 1996: 251). This can be the alignment of internal work activity to external temporal structures. Ancona and Chong (1996) show how daily rhythms of corporate life are strongly shaped by temporal structures in society at large such as the fiscal year or quarterly sales cycles. This can also be the mutual adaptation of cycles of activity in units that collaborate. One example is the alignment of business planning processes with individual performance appraisals. A central temporal alignment in the multinational Norsk Hydro was to adjust the timing of annual appraisals, so that appraisals could be based on recent and updated strategy plans with business objectives, on which individual performance targets should be decided (Lervik, 2005).

Organizations will often be influenced by several temporal structures emanating from larger society. Our biological rhythm of sleep patterns shape conventions for working hours. Our weekly rhythm of work and sparetime emanated from different religions' distinction between days for labour and prayer. Time off for vacations is shaped by a combination of the Gregorian calendar, religious calendars based on the lunar cycles, and the cycle of seasons that differ on the Northern and Southern Hemisphere.

Different temporal structures affect rhythm of work activity in their own small way. For organizations, some temporal structures are of higher strategic importance than others (Ancona, Goodman, Lawrence, & Tushman, 2001a). Organizations are likely to pace their activities to one overarching temporal structure; this can be the dominant technology life cycles for technology companies like Intel, who build entire value chains from R&D to manufacturing plants around each new generation of processor technology (Howard-Grenville, 2005). For others, like swimwear or ice-cream manufacturers, the seasonal demand variation may be the overarching temporal structure the organization is entrained to.

In the following, we examine the various aspects of a time lens and temporal boundaries with specific reference to one class of organizations where interdependencies over time are crucial, namely product service systems.

INTRODUCING THE EMPIRICAL ILLUSTRATION

Product service systems

Manzini and Vezzoli (2003) define a product service system as "the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services which are jointly capable of fulfilling specific client demands". Product Service systems encompass a broad range of modes of capitalist production, and Product-Service System providers are prevalent in several key sectors. Examples of product service systems include infrastructure for energy production and distribution, transportation infrastructure (railway and trains, toll roads, bridges, aircraft, ships), and turnkey manufacturing plants and manufacturing equipment in general. Companies providing such "products" increasingly complement the initial capital investment project with a string of services including maintenance and upgrades over the lifespan of the capital investment project. Service delivery may also become an important activity in itself, providing consultancy and management services to clients.

Temporal aspects of product service systems

There are several aspects of product service systems that make them interesting for studies of situated knowing and learning. First, they fully fit with Engeström's (2006) conception of the spatial and temporal expansion of objects of activity. The extended lifespan of a business interaction, in that suppliers of product service systems often maintain a relationship with the customer through the lifecycle of the capital project, providing advice, upgrades, maintenance and repairs etc. Installations are designed to last 20-30 years, maybe longer through midlife updates and upgrades. For example, commercial aircrafts are legally mandated to be supported with service and upgrades to keep them flying 50 years after the final production run. This requires suppliers to retain capabilities and expertise, which can be a key challenge.

Second, the longevity of installed systems means that while the rest of the organization may lead or keep abreast of technology cycles, service work often entails tinkering and bricolage on technology several generations removed from the "frontier". This temporal boundary between old and new technology adds challenges for service work that often requires help and support from the rest of the organization.

Third, product-service systems embody the tension in temporal dynamics between manufacturing and service work. Whereas manufacturing to some extent is loosely coupled and not determined by external temporal structures, the pace, rhythm and cycles of service work is by definition shaped by the temporal structures of their customers. You serve a burger when a customer asks for it, and you send a repair crew when the customer plant breaks down. Service work is more tightly coupled to external cycles and temporal structures. As we will show below, these conflicting temporal logics constitute a veritable temporal boundary limiting coordination and learning across the organization.

The case studies

We illustrate the concept of temporal boundaries and its implications for knowing and learning by drawing on ongoing research in four UK subsidiaries of multinational enterprises within Engineering and Aerospace industries. All four companies deliver systems integration projects to customers in the defence, aerospace, marine and industry sectors.

The companies are typically organized as a main "project delivery" organization [hereafter called "Projects"], encompassing departments such as commercial, engineering, manufacturing and commissioning. When an installation is handed over to the customer after installation and testing, Customer support [Hereafter called "Service"] takes over as the main point of contact for the customer. We might say that a temporal logic is the central organizing principle, in that the organization is compartmentalized and specialized according to what phase of the product life cycle they work with.

The companies vary in the complexity of products, the lifespan of installed systems, and the details of how projects and service is organized. Here, our ambition is not so much to provide a full-fledged empirical analysis of the four companies, but to highlight generic patterns of temporal boundaries that we find in two or more of the cases.

TEMPORAL STRUCTURES WITHIN SERVICE

Three of the four companies provide the actual service on the ground at the customers' factories and sites, and we have detailed data from two of those companies. We show how the service work is entrained by multiple, nested temporal structures, and these temporal structures influence service engineers' ability to collaborate and share within their unit, and even more so in their interaction with the Projects part of their organization.

In these two companies, service engineers engage in activities at customer sites that vary in their degree of planning, from the most structured to the least structured.

- Regular maintenance work. This entails going to customer sites at regular intervals, in one exceptional case up to 4 days a week.
- Planned overhaul, e.g. when a plant shuts down for say 1-2 days at certain intervals, yearly or less frequent. All contractors are called in to do service work which cannot be conducted when the plant is running.
- Non-critical problems. Customers may ask service engineers to look at some indicators of underlying errors when they have time to visit. This can be activities planned for the next week or the next time a regular visit is scheduled to the plant.
- Call-outs. The least structured element of work is call-outs, where customers have had a failure with serious consequences for productivity or health and safety.

The balance of activities vary between companies, Service engineers in company B do a lot of regular maintenance work, going to site weekly. Company M mostly carry out non-routine service activities related to overhaul, problem solving and upgrades.

Here we draw attention to nested temporal structures that service engineers' work activities are entrained to. We start with the proximate temporal structures that are most visible in the rhythm of their daily work.

The call out to repair a mission-critical failure

The first is the timing and pacing of an individual callout. When a drive fails at a manufacturing plant, or the propulsion of a ship fails, time is money. Most service engineers refer to and have an acute awareness of the cost of production downtime or a "stranded" ship. For customers with service contracts, there is a specified response time by which a service engineer should be on site to address the problem.

Pace

In one company this was 4 hours, and this timekeeping obligation had strong implications for degrees of freedom in organizational design. The company provided services to paper manufacturers in the UK. As the number of paper mills in the UK becomes lower, the response time and thus distance becomes a central parameter for setting up regional service units that can respond within a geographical area. Given that you need at least 2 service engineers on a call-out rota within 4 hours reach of any customer in the region, the 4 hour rule to a large extent determines geographical boundaries of certain regions, and by extension, who your closest colleagues are. As an engineer on a call-out, your job is to be at the customer site within 4 hours, and start to fix the problem. As an engineer you are on your own, but you have your colleagues you can draw upon for help and support.

Timing

Naturally breakdown can happen day or night, weekday or weekends. Service engineers participate in a call-out rota. Often they have to go to the customer out of hours, and they face a difficult technical problem that the customer itself has not been able to deal with. In these circumstances engineers emphasize the collegial support and their ability to call colleagues to discuss problems and suggested solutions.

We phone each other late, that's not a problem with our customer support guys. Because I'd like to think I could phone someone, so I allow them to phone me you know

However, this established sense of citizenship behaviour is only visible within the small local community of service engineers, those who cover the same geographical area, who meet at weekly briefings, and who speak to each other on the phone all the time.

The hours of call out service work is at odds with the established temporal structures guiding societal life and work life in general; The biological time of sleep patterns, the established convention of normal working hours and weekends off. You do not use your network or call a distant colleague in the middle of the night. You rely on your close community of colleagues. However, these collegial networks can be rather small. These networks to a lesser extent extend beyond the local. And because of the 4 hour call out, the local region can be quite limited, you only have a handful of colleagues to ask for help.

To sum up, the urgent pace of call out, and the often inconvenient timing (nights/weekends) means that service engineers have rather limited network of trusted colleagues they can draw upon.

The rhythm of interaction with a piece of kit

A "kit" is the individual installation of a system at a customer site. A system may be installed at several locations, but there are often local idiosyncrasies in the functioning of a "kit", due to how it is used (Orr, 1996; Tyre & von Hippel, 1997), or due to local adaptations that customers request or carry out themselves. The rhythm of interacting with a given piece is consequential for several reasons. Firstly, the skills of problem solving and repair are living knowledge that needs to be exercised.

Frequency

It's just we don't get to do it often enough to be honest, that's what the problem is. I mean we have training on [a particular kit] or something like that, which is fair enough, when you do it, that's great. You may not go on it for a year's time on a fault then, so you're scratching your head then, that's the problem, you're not doing it regular enough. (Service engineer)

The first issue of consequence for knowing and learning is the frequency by which service engineers are able to develop and maintain their skills and expertise on various pieces of kit. Service engineers often have to be broad generalists, covering all types of industries and installations within their geographical area. They develop generic diagnostic and problem-solving skills as they gain experience, and they draw on documentation of installed systems to identify problems. But often there is an intermediate knowledge that is required, such as the personal familiarity with a given kit, its history, its pattern of use. To develop and maintain that personal knowledge requires frequent interaction.

Time to learn vs. time to perform

A second issue is whether the service work affords a balance of *learning vs. performing*. First, does the external rhythm of planned and call-out service interventions afford a sequence of progression, where service engineers have the opportunity to spend some time engaging with kit in routine situations before being called out to perform under pressure? At call outs, they often face the added pressure of customer reps peeking over your shoulder and in one instance even capturing everything you do on video. Secondly, it is also a question of balancing time spent on low-pressure work vs. call outs. This is important both in terms of work-life balance as well as having sufficient opportunities for experimentation, play, and curiosity in engaging with kits as important elements of developing expertise.

However, call-outs to service faults also embodies opportunities for learning; according to one service engineer "you always learn the most when you're out on a fault and you've got to learn it there and then you know".

These issues are to some extent shaped by policies of the customers, some don't want to pay for preventive maintenance, whereas others do. What is more interesting from a temporal perspective is how the rhythm of service work is shaped by the reliability of a given technology, and the stage in the life cycle of a specific kit. We address these two temporal macro-structures next.

The life cycle stages of a kit

The rhythm of interaction with a customer kit is to a large extent shaped by the technological development. Technological development means kits becomes more reliable, and require less frequent overhauls. This trend is not new, Rosenberg (1982: 137)reports that already in the forties, scheduled shutdowns for power plants were stretched from one year to 2-3 or even 4 year intervals. There is a significant learning curve and performance gains in the cost of maintenance of equipment. Rosenberg (1982) reports that the annual cost of service of an aircraft engine in its 10^{th} year of operation was 30 % of the initial service cost in the first year. There are several aspects to this trajectory. In an early stage, there is often intensive interaction and error-correction. As a machine leaves the lab or the assembly hall, and is put to use, issues are discovered, some of which is related to the context of use (von Hippel et al., 1995). Often called the ramp-up phase, it is only through actual use some issues can be identified and sorted out.

As initial bugs are sorted out, an installation becomes more reliable. Initial service intervals may have been overcautiously estimated, based on limited knowledge with a product in use. Especially in the case of aircraft, one wants to be on the safe side, as the cost of error is very high (Rosenberg, 1982) As users and manufacturers gain experience, service intervals may be stretched.

As an installation comes of age, a different mechanism becomes salient. Individual components may wear out, and after a certain age, maintenance costs may increase again, as most of us experience with cars.

The transformation of equipment through stages of its lifecycle has implications for knowing and learning in each stage. We single out three aspects, 1) how the initial phase ramp-up phase constitutes an important arena for learning and feedback, 2) how asking for help becomes more difficult as technology ages, and likewise 3) how the receptivity for feedback in engineering and designers wanes as they shift their attention to new generations of technology.

Ramp-up as a temporal window for learning

Working on the initial ramp up is mostly done by specialized commissioning people. The work is characterized by a very steep learning curve. In addition you often work intense, long shifts at offshore customer locations. Some people then move on from Commissioning to other parts of the organization, as this affords a better work life balance.

Service engineers we spoke to were to varying degrees exposed to commissioning work, and those who had done it, all emphasized the value and learning they gained. In some cases, project managers consciously try to involve service engineers in commissioning work to facilitate a smooth handover from projects to In-service. This is similar to Ancona et al.'s (2001b) notion of temporal overlap, which facilitates coordination between workers of one shift and the next.

Asking for help on old generations of kit

> And it's the same with our kit as well, all the newer stuff […], they go in and they get commissioned and then they're around for five/six years or whatever. We tend to go in there on breakdowns when it's old.

As reliability increases, service engineers often first get exposure to certain kits when systems have been around for some time. This underlines the issues above of maintaining expertise and balancing learning vs performing discussed above. An additional issue is the temporal boundary between a 9 year old kit today, and those who designed it 9 years ago.

> if you want expert advice up in [engineering location], it's like getting blood out of stone because they've all moved on, they developed that stuff 15 years ago…… because like once they develop it up at [engineering location], they move on to the latest thing all the time and they forget that all the older stuff is still going.

Service work will in many instances rely on asking for help from colleagues. Problem solving activities in general is a social process, and studies show it hinges considerably more on the ability to consult other people, rather than to consult various databases and knowledge repositories (Cross & Sproull, 2004). With the time lag between the design of a system and when service/maintenance is required, the options for enrolling help from others is rather limited. Engineers have "moved on" and are either not particularly interested or may have problems tuning in to a class of problems they have not dealt with in a long time.

Learning from old kits

The time lag between design and service of a kit also creates barriers for learning and knowledge sharing in the other direction. Service work on old kits may highlight recurrent issues with a particular kit, or more generic issues that may be of importance to engineering.

I: So it's kind of recurrent issues that you discover that design engineers need to know …?

R: Yeah but it's all 15 years too late you know, so they're not going to do anything about them anyway because they're all getting to the stage where they're quite old, so they're not spending any money … there are some new things that are going in but it's just on a small scale now.

The companies had certain mechanisms in place to capture "learning from use" from service engineers. In one company – selling and servicing ship turbines – service engineers worldwide participated in training programs at division headquarters, where they were briefed on new products etc. Every engineer was supposed to participate once every two [?] years. At these seminars, there was also a session where the head of engineering sat down with engineers to capture their ideas for improvements to products and processes. One tangible example was an initiative to map engine room layout of ships, so that crucial information about access, needs for special tools or equipment could be made available in the preparatory stage of a service intervention, and that e.g. the need for special equipment was not discovered once on board. Other companies had less committed approaches, one service engineer reported having received an email sent to all service engineers from the product department. They were now going to launch an upgrade of product X, did anyone have any input?

Overall, it seemed like this time lag contributed to a barrier between service engineers and design. Design "had moved on" and did not really learn from the (potentially) useful input from service engineers. Service engineers on the other hand weren't sure if their input was required, encouraged, or valued. And they weren't sure if they had something useful to contribute.

DISCUSSION AND CONCLUSION

The purpose of this paper was to highlight that situated activity has a time dimension as well as a spatial dimension. Time is always there in our accounts of organizing, but rarely do we focus theoretically on time and its implications for knowing and learning.

We have applied a temporal lens to throw light on temporal dependencies and boundaries in a setting where time is expected to be especially important and relevant. Providers of product service systems maintain relationships with installed systems and clients of long lifecycles of product service systems, sometimes up to 50 years. Work activities on product service systems thus always need to take into account the history of a particular kit (how it was designed, its service record and modifications), and also needs to keep an eye on future contingencies (designing systems for flexible adaptation, designing systems that are easy to service, modify etc).

We have focussed on the service activities pertaining to product service systems, and we have pointed out how these activities are to a large extent shaped by – entrained – by nested temporal structures shaped by customers and technology cycles. We further show how these various temporal structures of service work are "out of sync" with temporal structures guiding rhythm of work in other parts of the organization. Service engineers may need to call colleagues for advice in the middle of the night, and can only call close, trusted colleagues where there is a high amount of goodwill. Furthermore, service work on old generations of technology may find it hard to receive support and advice from the projects organization, as project engineers have move on to new technologies and projects, and take less interest in yesterday's technology.

Product service systems entails a type of organizations where temporal interdependencies are particularly important. We hope to see further work to explore the role and impact of time in other contexts and organizations as well.

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