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Research Article

Conflicting Epistemic Cultures and Obstacles for Learning across Communities of Practice

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This paper addresses the challenges that arise when knowledge production occurs in cross-disciplinary settings. To date most studies on communities of practice have focused on knowledge production within communities of practice rather than across communities of practice. We analyse the various professional groups in a medical R&D department as a constellation of distinct, but interconnected communities of practice with different epistemic cultures. The medical R&D case is particularly interesting for this purpose, because it involved creating new cross-disciplinary practices between different pre-existing and well-established communities of practice. In line with our focus on the challenges and processes involved in cross-disciplinary knowledge production, we describe negotiations and tensions during the establishment of the department, as well as in day-to-day practice. In particular, we focus on how the 'machineries of knowledge production', that is, the actual mechanisms by which knowledge is pursued, are different across the various communities of practice. These machineries belong to different epistemic cultures on a national or even international scale, and thus every community of practice is part of a complex web of people, activities and material structures extending well beyond the immediate work context. This networked character of knowing in practice explain why learning on the system level of communities of practice can be challenging. It may lead to path-dependent learning processes, and radical change can become limited if the knowledge required by new and different practices is incompatible with the existing stock of knowledge. Consequently, we suggest that the communities of practice approach could be enriched by looking at diversity and discontinuity in the epistemic cultures and networks that the different communities of practice are associated with. Copyright © 2008 John Wiley & Sons, Ltd.

INTRODUCTION

The community of practice (CoP) approach (Lave and Wenger, 1991; Brown and Duguid, 1991) has

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become increasingly influential for explaining the relationship between practice, learning and innovating. Innovation is here conceptualised as 'something that generates and facilitates change of practice' (Tuomi, 2002: 10). By emphasising how learning and practice are socially, culturally and historically situated, it offers a radical critique of the cognitivist learning theories (Handley *et al.*, 2006). Learning consists of becoming skilled practitioners in communities of practice (CoPs) (Brown and Duguid, 1991), and cannot be reduced to mental processes (Gherardi, 2000, 2006). Wenger (2000) argues that CoPs are the basic building blocks of social learning systems, and knowing becomes a matter of displaying the right competences.

'Shared practice by its very nature creates boundaries' (Wenger, 2000: 232). These boundaries offer both potential difficulties and possibilities through connecting CoPs, increasing the value of membership and offering learning opportunities. Indeed 'there are practices that traverse the boundaries of several communities and which (...) create a network of relations within a constellation of communities of practice tied together by interconnected practices' (Gherardi and Nicolini, 2002: 419). To overcome such boundaries different means have been suggested, such as 'boundary objects' (Star and Griesemer, 1989), 'translators' (Brown and Duguid, 1998) or 'knowledge brokers' (Wenger, 1998), 'boundary interactions and cross-disciplinary projects' (Wenger, 2000). Carlile (2002) and Bechky (2003) have elucidated processes whereby different CoPs communicate across boundaries through processes of 'perspective making' and 'perspective taking' (Boland and Tenkasi, 1995).

In organisations occupied with highly cross-practices knowledge boundaries may become particularly acute (Swan *et al.*, 2007; Robertson, 2007). This calls for examining the more fundamental problems of how CoPs are based on different epistemologies. Van Maanen and Barley (1984) and Bechky (2003) take interest in how knowledge is developed and reproduced within 'occupational communities'. Knorr Cetina (1981) and later Haas (1992) use the notion 'epistemic communities' to denote groups of people involved in the production of knowledge. Drawing on Fleck's (1979/1935) notion of 'thought collective', Dougherty (1992) uses the term 'thought worlds'. Boland and Tenkasi (1995) use the notion 'communities of knowing'. In this paper we prefer 'CoPs', and argue that knowing and practice is 'reciprocally constitutive, so that it does not make sense to talk about either knowledge or practice without the other' (Orlikowski, 2002: 250). To date most studies on CoPs have focused on knowledge production within CoPs and not on knowledge production across CoPs (Gherardi and Nicolini, 2002). To address this gap in the literature we follow Knorr Cetina (1981, 1999) by focusing on the 'machineries of knowledge production' and on the mechanisms by which people do their work. Hence, the aim is to offer insights into the challenges and processes involved in cross-disciplinary knowledge production, or in other words; the aspects influencing 'epistemic work' (Cook and Brown, 1999). To achieve this we ask: What challenges may CoPs based on different epistemic cultures face when they need to collaborate to develop new practices?

The ideal setting for studying this topic, we argue, is innovative organisations, where new patterns of collaboration are explored. We have examined a medical R&D department developing novel surgical imaging technologies, since medical work often have a cross-disciplinary and heterogeneous nature. Many breakthroughs in knowledge fail to be translated into medical practical, because they cut across professional boundaries, and as they do not align well with the existing practices (Newell *et al.*, 2006: 117). Moreover, as learning processes within these CoPs may become 'path-dependent' (Arthur, 1994), the ability to integrate knowledge across these communities is important. Hence, our analysis describes how much innovative work has been carried out emphasising why cross-disciplinary knowledge production might be challenging. In doing so it highlights how different epistemic cultures constituting these CoPs may inhibit learning at the level of the 'social learning systems' (Wenger, 2000).

In what follows we outline the theoretical background. We shall then look at the methods used. We then turn to how learning happens, as well how various epistemic barriers can make learning and innovation processes challenging. Finally, the contributions and implications are highlighted.

THEORETICAL BACKGROUND

In the late 1980s, some of the main assumptions of the cognitive perspective on learning were challenged (Lave, 1988; Brown *et al.*, 1989), and a situated approach to learning integrating the historical, political and social conditions was introduced. For Lave and Wenger (1991: 35) learning is conceived as 'an integral part of generative social practice in the lived world'. A CoP is, according to Lave and Wenger (1991: 98), 'a set of relations among persons, activity and world, over time and in relation with other tangential and overlapping communities of practice'. In CoPs 'legitimate peripheral participa-

tion' is a central process, referring to how newcomers are given relatively simple tasks, where errors have relatively minor consequences. These tasks are nevertheless useful contributions, which is why one is accepted as a participant.

Brown and Duguid (1991) argue that learning is essentially about becoming a practitioner, and since these communities constantly improvise and adapt their behaviours to traverse the limitations of formal organisation, they are important arenas for local invention. Hence, CoPs 'exert a crucial influence on the integration of knowledge required within innovation processes because they both emerge from, and shape, network relations' (Swan *et al*., 2002: 480). Wenger (1998: 73) describes three dimensions by which practice is the source of coherence of a CoP: mutual engagement, a joint enterprise and a shared repertoire (See Figure 1).

Wenger (2000: 227, 228) distinguishes between three modes of belonging: *engagement*, achieved through doing things together, *imagination*, achieved through constructing images and *alignment*, achieved through aligning local practice with other processes.

According to Wenger (2000), the most important learning processes takes place at the level of social learning systems, that is, when knowledge is transferred from one CoP to another. Meanwhile 'shared practice by its very nature creates boundaries' (Wenger, 2000: 232), and experiences may be modified and extended in the light of experiences in other fields. Wenger (2000: 235) identifies three ways of bridging these boundaries: people acting as brokers, artefacts (boundary objects) and interactions among different CoPs. In cross-disciplinary projects 'people confront problems that are outside the realm of their competence but that force them to negotiate their own competence with the competence of others' (ibid: 238).

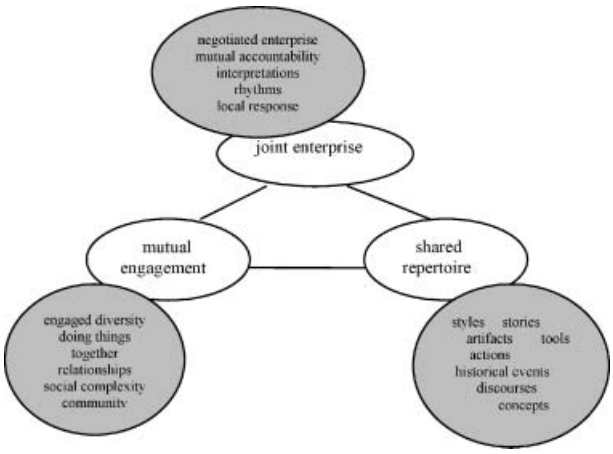

Figure 1 Dimensions of practice as the property of a CoP

Brown and Duguid (1998, 2001) emphasise that innovation and learning can be encouraged within CoPs, but across this may be difficult. Swan *et al*. (2002: 478) underscore that: 'established communities of practice may, then, pose problems for the development of radical innovations that cross such communities'. This resonates with Carlile (2002), Hislop (2003) and Mørk *et al*., (2006) who show how CoPs and boundaries both enable and constrain learning and innovation.

In many areas practices are shared widely among practitioners, and Brown and Duguid (2000, 2001: 205) therefore describe them as 'networks'. Reflecting that practice and knowledge is what binds them together they call them 'networks of practice' (NoP). Brown and Duguid (2001) and Duguid (2005) point at how the 'epistemic culture' (Knorr Cetina, 1999) of high-energy physicists constitutes a global NoP with multiple local CoPs. Scientists within each of these NoPs can communicate and collaborate with colleagues around the world, as practice is common to all members. But, 'networks of practice, like professions, may have constraining effects on innovation processes that require the integration of knowledge across communities' (Swan *et al*., 2002: 480). Duguid (2005: 114) underscores:

> But when the practice and knowing of how two communities are different, epistemic barriers develop and productively sharing knowing becomes more challenging—even when the different practices lie together within an organisation.

To overcome this incommensurability an ability to take another CoP perspective into account is required (Boland and Tenkasi, 1995). Gherardi and Nicolini (2002: 420) emphasise:

> In a constellation of interconnected practices, discourse among communities is a specific practice whose aim is not only to reach understanding and/or produce collective action, but also to foster learning by comparison with the perspectives of all the co-participants in a practice . . ..

Fox (2000: 860) notes that 'community of practice theory tells us nothing about how, in practice, members of a community change their practice or innovate'. Over time these CoPs may become resistant to radical change, and learning within CoPs may become path-dependent as new knowledge often reinforces existing preferences (Roberts, 2006: 630). To date the literature better describes learning within single harmonious CoPs, than how

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'knowledge remains isolated and not communicated from one community to another' (Gherardi and Nicolini, 2002: 420). To address this gap in the literature we focus on how the different epistemic cultures may limit the learning taking place on the overall 'system level' of these constellations of CoPs.

To identify and discuss these challenges we draw upon Knorr Cetina's (1999) notions of 'epistemic cultures' and 'machineries of knowledge production'. Just as the notion of 'CoP', they are based upon a contextual perspective on knowledge. While the notion of 'CoP' assumes that knowing is embedded into and inseparable from practices shared by CoPs, the notions of 'epistemic machineries' and 'cultures' bring our attention to the machineries involved in knowledge production. Knowledge production is shaped by and cannot be separated from the machinery used for its production and the culture within which it is embedded, an argument that resonates with Wynne (1996) and Gherardi (2001, 2006).

Knorr Cetina (1999: 1) defines epistemic culture as 'those amalgams of arrangements and mechanisms—bonded through affinity, necessity and historical coincidence—which, in a given field, make up *how we know what we know*' (italics in original). Her definition of 'culture' is rooted in practice, and refers to the aggregate patterns and dynamics in expert practice. Epistemic machinery defines those methodologies, techniques, tools and instruments used in our knowledge production and distribution. What interests Knorr Cetina is not the production of knowledge, but rather the construction of 'the machineries of knowing', both social and technical. She argues that magnifying this aspect of science reveals the fragmentation of contemporary science; it displays different architectures of empirical approaches, specific constructions of the referent and particular ontologies of instruments. In other words, it brings out a diversity creating 'epistemic monopolies' within various fields that produce vastly different products. The recognition that knowledge domains are heterogeneous runs counter to the assumption about the unity of science associated with the Vienna Circle (Knorr Cetina, 1999: 3).

Knorr Cetina develops her concepts through an empirical exploration of the epistemic cultures and machineries of molecular biology and high energy physics. In spite of the empirical focus on the sciences, her aim is to provide an analysis of what is commonly held to be our emerging knowledge society. It is not simply a society of more experts, more technological gadgets and more specialist interpretations, but a society permeated with knowledge cultures where knowledge fields are characterised by an unfolding ontology supporting the enlargement of knowledge (Knorr Cetina, 2001). The emphasis is thereby turned to knowing as practiced—within structures, processes and material and economic environments—that is, a definition of knowing close to that of practice-based studies.

METHODS

We have conducted an ethnographic case study of a medical R&D department called the Interventional Centre (hereafter the IVC) at Rikshospitalet University Hospital HF, the University of Oslo, Norway. Their primary task is to develop new practices for diagnosis and treatments utilising new digital imaging technologies and various forms of minimally invasive procedures, such as keyhole surgery. These new technologies require close collaboration between surgeons, anaesthetics, engineers, nurses, radiologists and radiographers. (A radiologist is a medical doctor specialised in imaging. During traditional pre-surgery imaging, the radiologist interprets the image and reports on the findings, without necessarily seeing the patient. During a radiological intervention, such as angiography, the radiologist is present, places the catheters and evaluates the results based on the images. A radiographer handles the imaging equipment, and usually performs the actual imaging. Radiographers are not doctors; their education is more similar in length to the education of nurses, but with more emphasis on technical knowledge.) Drawing on Gherardi and Nicolini (2002), we consider these groups as a 'constellation of different, but interconnected communities of practice'.

We employed an interpretative approach with interviews, observation and document analysis. An important source of information has been the observations two of the authors did when we were involved in the day-to-day activities of the IVC as PhD scholars (BEM 2002–2006, MA 1998–2001). We followed closely the emerging discussions and disputes, and observed events of self-presentations of the IVC in meetings, seminars and in the media. From 2000–2005 BEM also participated in several projects.

In total we conducted 35 semi-structured interviews of the head of the department, surgeons, one radiologist, engineers, the secretary, radiographers, operation nurses and anaesthesia nurses. The interviews lasted from 45 to 90 minutes, usually around 60 minutes, but occasionally up to 270 minutes and all of the interviews have been fully transcribed. We then coded the research material, and organised it into matrixes to get a better overview (Coffey and Atkinson, 1997). Our

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approach was exploratory to develop insights, and inspired by grounded theory (Glaser and Strauss, 1967; Strauss and Corbin, 1990). We have also looked at internal reports and published articles. As writing the case study was an iterative process, we revisited our research material several times. In this process certain themes emerged that seemed more relevant than others. We then shared our findings and interpretations with our informants, and these discussions sharpened our interpretations.

ORGANISING FOR CROSS-DISCIPLINARY LEARNING AND INNOVATION

During the latter decades new medical imaging technologies have emerged and blurred the boundaries between diagnostic and therapeutic work. Most imaging techniques (e.g. x-ray and magnetic resonance imaging) were initially developed and used for diagnostic purposes, like pre-operative examinations. However, in the 1990s radiologists started doing simple interventions when the patient was on the examination table. Guided by images, small balloon-tipped catheters were inserted into blood vessels to expand partly blocked lumens. Similarly, surgeons started using imaging techniques, not just for pre-examinations, but for imaging support during the operation. Ultrasound or videoscopic techniques became increasingly used requiring that surgeons ventured into the area of image interpretation in order to perform the surgery. This blurring of boundaries between the practices of radiologists and surgeons necessarily evoked conflicts and each group claimed 'ownership' to the treatment and to the patients eligible for it.

Despite these disputes, the indisputable benefits of the less invasive therapies were recognised by both groups. Thus, the IVC was established as an independent hospital department in 1996 as an attempt to transcend the stifling 'turf battles' through creating 'neutral ground' for further research and development of interventional radiology and image-guided surgery (Fosse *et al*., 1999). With its cross-disciplinary team of doctors and engineers the vision was to be a shared resource and a 'common toolbox' for all medical specialties to use.

In 2007 the IVC is in its 12th year of operation, and there has been a steady growth in personnel (currently 60 people) as well as in the scope and size of activities. The IVC has treated over 5000 patients, developed over 20 new procedures, filed 12 patent applications, published over 200 scientific publications and 13 PhD projects are completed (currently 27 ongoing PhD projects). The IVC can therefore be seen as a highly successful attempt to develop new cross-disciplinary practices. Our informants emphasised several reasons for this:

- Availability of high-tech, expensive equipment and technical support.
- The personal relationships between individuals working in physical proximity.
- Motivated staff sharing a common vision.
- The (relatively) sheltered role as a R&D department and not just a production department, having the time to do procedures of long duration and the formal permission to use animals for training.

The overall efficiency and quality of the procedures developed at the IVC depends on how each CoP carries out its work. Accordingly, all of them need to develop the required 'knowing in practice' (Nicolini *et al*., 2003; Orlikowski, 2002) for how to perform their tasks. However, the practices of the different CoPs are interdependent which implies that they need to learn cooperatively so that the practices of one CoP align well with the practices of others CoPs. Hence, the learning process required for the development of high quality procedures need to be one where each CoP learn in a coordinated way. Indeed, developments of high quality medical practices depend on the learning taking place at the system level.

In the following, we provide some examples of how learning and innovating do not happen in a vacuum, but is affected and possibly hindered by what is already there. We start by describing how learning happens. Then we turn to examples of how different aspects may become obstacles for learning. We do not want to explain these challenges by looking at power relations or by blaming somebody for 'resistance' to change. Since our research aim is to explore the challenges that cross-disciplinary and radical learning encounter, we will naturally focus on instances of debate, controversies and challenging issues, rather than the many successful instances of learning and innovation.

Negotiating the IVC's organisation and location

In attempting to create a common ground for cross-disciplinary work across specialist boundaries, a certain degree of 'diplomatic work' has obviously been necessary. We may discern evidence of negotiations and compromises along the way, and one example is the location of the IVC. When the centre was established in 1996, it was not located within any of the already existing hospital

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buildings. Instead a new building was erected on 'neutral ground' in the hospital park area, where no single group (i.e. medical speciality) had any special claims. (When the hospital moved into new facilities in 2000, the IVC had an integrated, although somewhat peripheral location.) The rooms within the building where the medical procedures were performed, were equipped like combined radiological examination rooms and operation theatres, but were formally classified as radiological laboratories. A balance between radiologists and surgeons in the staff, both in general and at the top level in particular, has always been explicitly pursued. The head of the department is a thoracic surgeon, which was problematic as it opposed the traditional model of professional collegial leadership.

> According to one informant (Surgeon 1), the National Medical Association discussed the organisation of the IVC. The question was whether a surgeon could be the leader of a department with radiologists and anaesthesiologists.

There have been continuous economic, organisational and political disputes around ownership of patients and procedures between the different departments involved. These disputes were centred on which department should supply the IVC with the necessary personnel, who should pay for the technology and consumables used in the procedures and who should decide on the patient treatment. We recount these tensions, conflicts and negotiations as examples of how cross-disciplinary learning is not smooth and unproblematic. Still, learning can and does occur, as our next example vividly illustrates.

Negotiating practice

Negotiations also take place in the day-to-day work, where novel medical practices are to be designed and tested. A very good illustration is how nurses and radiographers cooperate in defining novel ways of sharing tasks. In conventional radiological laboratories performing interventional radiology, the radiographer takes care of patient positioning on the table, the hygienic measures and the preparation of instruments, as well as assists the radiologist during the treatment. Occasionally, radiographers enter ordinary operation rooms with the particular task of taking images (using mobile x-ray equipment), but usually there is no direct cooperation between operation nurses and radiographers. The operation nurses' primary concerns focus on sterility and patient care, including proper positioning of the operation table to avoid pressure sores, pain etc. In order to do this they often use gel cushions to support various body parts. The patient may also be covered with hot air blankets. This is unfamiliar to the radiographers, even if they have worked with interventional procedures, which usually are shorter in duration and thus does not require as much precautions. The primary focus for radiographers are on achieving optimal image quality, and the use of mattresses, cushions and blankets can conflict with this. These artefacts may absorb, deflect and scatter radiation and to achieve a sufficiently good image may require that the patient will be exposed to a higher dosage of radiation, which is not desired. Such disputes, which may arise when previously unconnected practices meet, were usually solved in the work practice. For instance, concerning this particular issue, the nurses and radiographers were able to identify and purchase mattresses that did not absorb radiation.

CHALLENGES FOR LEARNING AND INNOVATING

We will now look at other aspects shaping the cooperation between the various CoPs at the IVC, and the ensuing learning and innovation. There are multiple ways in which each group has relations and obligations beyond their immediate work surroundings. What we describe as 'internal' CoPs, the various professional groups within this department, can equally well be seen as parts of NoPs, the NoP of the profession. This has implications for the degree of freedom they experience in their everyday practice and local work situation. The following section offers several examples of how various aspects beyond the immediate work situation impacted practice at the IVC.

Identity

The issue of identity turned out to be central. For all groups work at the IVC involved changes in practice and roles compared to an ordinary setting:

> It is painful to let go of your identity. You invest quite a lot when you spend many years on your education. For some individuals it is impossible to let go of their identity, and they will work in their traditional way until they retire [. . .] when it comes to the professional roles, it is built into the whole structure of the health sector. It is actually built into the whole structure of the society. People get an education, they are part of a profession and then they are supposed to work as

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> a professional. To change this is a big process (Surgeon 1).

Meanwhile many of the informants expressed excitement:

> I don't think I'm able to go back and work in an ordinary department any more. There I was just a cog in the wheel and didn't have any scope of influence on my work. Here I have a lot more responsibility and freedom. For example, for new procedures, I have to find out what instruments are possible to purchase and then I have to get them. I can try out new materials and practices . . . I get to learn a lot more about technology (Nurse 1).

The engineers underscore that it is rewarding to see their technical competencies being valuable in such a setting. Others value the scientific training they receive through working there, or the chance to develop their administrative skills.

However, some also expressed recognition that they 'loose' touch with what's going on in their own area: 'I don't develop in my own field, and it is frustrating not to have any other individuals to discuss issues that are related to my profession' (Radiographer 1). Quite a few of the informants talked about the need for 'a critical mass' of colleagues within their own field: 'At the IVC you learn a lot of skills that are not related to your specialisation. We are below the critical mass when it comes to the ability to be updated in our specialities' (Surgeon 2). Even though the informants had to change their professional identity, some of them were excited about the opportunities that the practices at the Centre offered them: 'My identity as a professional has changed, and I can do many different things, since I learn from all the different groups' (Nurse 1). In other words, there seems to be individual variation with respect to whether this is seen as problematic or not. The informants suggest or employ different strategies for maintaining links to their profession: leaving the IVC for a period to work in an ordinary setting, maintaining ties with the professional associations (e.g. through meetings, journals and courses), or to pursue further formal education and specialising.

Legal and formal regulations shaping work conditions and practices

Agreements with the doctors and the nurses' trade unions regulate the demands individuals have when it comes to office space. Senior doctors working in their offices 8 hours a day should have 8 m^2, while junior doctors sharing offices have 4 m^2 each. Nurses are not entitled to offices, unless they have administrative work, hence only a rest room is required. For engineers there are no formalised agreements, as they are not a large personnel category at hospitals. At the IVC all doctors as well as engineers had their own individual office spaces, either in single or shared offices (2–4 people). One office was shared by a doctor, an engineer and a sociologist, while the nurses and the radiographers shared one office with six computers.

Formal agreements between the hospitals and the trade unions also regulate work hours. The nurses had a coordinated work list specifying the days and time slots where they are supposed to work, while the engineers did not have this. The nurses and the doctors allocated to specific procedures during the day had to adjust to the schedule (e.g. show up at a given time in the morning, 7.20 for the nurses, somewhere between 7 and 8 for the doctors). The engineers arrive when they prefer, unless a procedure in the operation room required their presence. To curb extensive use among any personnel category of this freedom, a 'core time' between 9 a.m. and 3 p.m. was introduced where everybody should be present. Whereas nurses were reluctant to spend their spare time at work, the doctors and the engineers with academic ambitions often stayed long hours.

Standardising learning as 'doing research'

Many of the doctors and engineers associated with the IVC were working on their PhDs. Publishing academic writings were highly valued at the IVC, and our informants regarded research as a crucial for the IVC. 'Doing research' was by most associated with pursuing an academic degree, like a PhD or a Masters Degree or with the continuous work required for an academic career after a degree had been obtained. Beyond generating new knowledge, research results should be presented on conferences or published in academic journals. Engineers and doctors frequently went away on international conferences to present research results, and the radiographers have been active in their professional associations' course activities. On several occasions the nurses at the IVC have been encouraged to 'do research', and some of them have taken a Masters Degree and/or participated in research seminars.

Within the medical world there are highly standardised methods for knowledge production. The form of results and the methods to generate and report them are subject to well-established and widespread rules. The scientific ideals correspond

to the natural science ideals of objective, repeatable and falsifiable research (positivist ideals) and much emphasis was laid on methodological rigour. The first two authors of this paper perceived that the qualitative interpretive approach they used was not immediately appreciated by everyone at the IVC. Also during the interviews some of the informants questioned our research design. Many of the research projects involved lengthy and large studies generating enough data for statistical analysis of outcomes.

Such a construction of research scared away or inhibited the nurses from defining their work as research, even though they did a lot of new knowledge generation. During our interviews, all of the nurses and radiographers were aware of both the high status allocated with 'doing research' and the wish that they should engage in research, but they usually underscored that they had no training or culture for doing research, as there was no emphasis on this during their education. Nursing education is practice-oriented to a larger degree than medical training, and the institutions of nursing science have not achieved a position that is comparable to the institutions of medical science, neither within hospitals nor in the academic world. Most of the nurses state that they are 'not after titles'. Neither did they want to spend much of their spare time working or dedicating themselves to large-scale projects where no results would be visible until years had gone by. One nurse expressed critical views on research taking the focus away from patient needs, and even possibly being conducted against the best interest of the patients. The nurses' main focus was on improving their practice, and some expressed recognition that this work was unrecognised and did not count the same way as research activities, which was equated with being 'clever'.

Still they recognised the value of reporting problems and solutions to other colleagues, a focus which they found much more motivating than the traditional research emphasis. Such studies might look more similar to reports than academic papers. When discussing these issues during the interviews, several possible themes for systematic studies were suggested: for instance, anaesthesia nurses might investigate the special demands for anaesthetics for each new procedure, which have different characteristics (e.g. when it comes to finding a satisfactory pain killing regimen during recovery). When thinking about doing their own research projects, they were not sure whether the required resources would be available for them on line with the doctor- or engineer-initiated projects, for example, reserved time in the operation theatres. The nurses and radiographers also expressed doubt on whether they would have the mandate or authority to enrol others (especially doctors) to join and contribute.

How different epistemic cultures influence learning

Above we described how the scientific ideals associated with 'doing research' seemed quite far away from what the nurses were comfortable with. However, it seemed that the epistemic cultures of doctors and engineers were more compatible, so the engineers had fewer problems in finding an acceptable position within the medical research tradition. But also this cooperation has not taken place entirely without tensions. On the one hand some of the engineers expressed a critique of the doctors' 'sloppiness' in examining and reporting technical matters from projects. On the other hand, a doctor countered this by requesting the engineers to modify their 'idealistic' methodological demands in order to arrive at practically feasible procedures that would work in a concrete clinical situation. Engineers also suggested defining projects based on a technological motivation rather than just clinical, based on the perception that doctors did not have the necessary skills for choosing optimal technical solutions to problems. Moreover, much technical research has an exploratory and constructive orientation, which is not immediately appreciated within medicine. This became evident with respect to joint (engineer-doctor) research publications, of which some were in journals with a focus on medical-technical issues, while others have been published in medical journals. The quality-focus in the highly competitive medical academic world manifests itself in, among other things, the emphasis on the ranking of academic journals, from the large, international, peer-reviewed, high-quality journals to the ones with a lower 'impact factor'. The MEDLINE database lists international medical publications in most high-quality refereed journals, and a journal's editor usually double-checks an article's references against this database. Thus, they did not immediately accept the engineers' references to technical journals and to technical conference proceedings in these joint papers. While peer-reviewed conference papers are a legitimate publication outlet in technical disciplines (sometimes having a status almost equal to that of journal papers), publications at medical conferences are usually not full papers, so only journal papers 'count'. Thus, the editors in the medical journals would usually request checking and elaboration of the references, and occasionally they would also request removal of references that pointed to 'just' conference proceedings.

Division of labour in research activities

Some of the IVC's activities are exploratory development of equipment and procedures, which by its nature cannot be pre-defined. Other activities are part of formal research projects, with a pre-defined 'protocol' and a clear research agenda. The projects are designed and run by doctors or engineers, and are usually fairly much defined before they are presented to the staff at the IVC. Nurses are rarely part of the team designing the project in the first place, but they must of course be included when the specific requirements for equipment and clinical work shall be defined. The nurses are usually seen as support workers, who do their tasks regardless of the research projects the actual patient belongs to. This also seems to be the case, although to a lesser degree, with radiographers and engineers, who have crucial technical knowledge.

Several of our informants argued that this preserves the traditional ways of working, and that it may preclude the project from harnessing the possibilities of 'truly cross-disciplinary work'. Radiographer (2) explained:

> 'In many projects the radiologists could have contributed with their knowledge. The same can be said about other professions. The radiographers and the engineers could have co-operated more. The radiologists and the surgeons could have co-operated more. It is necessary to define all groups as possible contributors'.

A nurse (3) said: 'Certain professions set the premises in the project, and thereby exclude others. This hinders truly cross-disciplinary work'. If the project designer asked for the input from the whole group, not just the people he/she thought would contribute, unexpected suggestions and corrections might emerge. Nurses and radiographers often said that they could have contributed earlier, during project design and set-up (e.g. practicalities around need for personnel and equipment etc.). Some suggested an open 'brainstorming' session before the formal project team was settled to see who could contribute with what. As it is, the different individuals and communities work in parallel and coordinate only as much as necessary, but not leveraging really on the potential for 'true cross-disciplinary work'. Work is usually 'multi-disciplinary rather than cross-disciplinary', in the words of one engineer (1). Also between doctors this may lead to limited degree of cooperation, it is restricted to the obviously necessary input from other doctors. Doctors are usually not participating in more projects than they 'have to', even though it could have created novel knowledge.

Marginalising knowing in practice

We might wonder whether there are any adverse effects of this narrow focus, and some of our informants provided evidence to support such a view. One effect is that consequences or pre-requisites for successful deployment will only be known after the project starts. For example, an anaesthesia nurse described how the post-operative pain patterns changed when starting feasibility studies of a new therapy.

> When we induce massive ischemia like we did in that project, the pains will be immense and they will start very soon after the procedure is finished, sometimes before we wheel the patient out the doors. But this was only visible to us nurses, since the anaesthesiologist is not always there at that point' (Anaesthesia nurse 1).

This aspect was not the focal point of any of the researchers, and the postoperative pain-killing medication regime had to be changed in an ad hoc manner. The same nurse also tells:

> The same medication for these procedures has been used for the last 5 years, even though they have become much larger. We nurses have the impression that the patients have larger post-operative pains than before, but the surgeon doesn't believe that and doesn't want to introduce for example epidural, because that will make the patients stay longer in bed postoperatively. And we haven't had any data to justify our opinions [. . .] so; we have started our own research project to systematically document post-operative pain.

If this had been prepared, involving a systematic assessment based on planned data collection, it would not only have provided better patient care; it would also have enabled this part of the work to be published as a separate research contribution. The current practices around protocol definition are a remnant of the specialisation approach, the disciplinary reduction into clearly delineable problems, rather than a comprehensive approach. Thus, the problem is that the unexpected may emerge 'outside of' the defined project, and whether it is discovered or ignored is to some degree governed by chance.

DISCUSSION AND CONCLUSIONS

We have described the IVC as an arrangement of organisational collaborative structures and material

structures (buildings, offices, technologies) allowing learning to happen through developing the practices required to get the potential benefits of new technology. The case also illustrates that such arrangements involve bringing together partially incompatible CoPs, which implies that learning occurs in a context of potential tensions and conflict. However, much cross-disciplinary learning does happen, for example, radiologists and surgeons have managed to redistribute and share the new 'territory' opened up by new technological possibilities between their respective groups through processes of 'perspective making and perspective taking' (Boland and Tenkasi, 1995). This could therefore have been yet another paper on of how CoPs can be 'cultivated' (Thompson, 2005; Wenger *et al*., 2002) to become an important source of learning and innovation. However, we believe that such an approach is better at explaining processes of learning and innovating within single harmonious CoPs, than at describing processes in the spaces between CoPs. The purpose of this paper was therefore to contribute to this latter gap in the literature by offering insights and stimulating to reflections on the challenges and processes involved in cross-disciplinary knowledge production. Our case allowed us to study a 'constellation of interconnected practices' (Gherardi and Nicolini, 2002) in a medical setting, with an emphasis on the changes of practice at the system level, rather than at changes of practice of an individual, a group or a CoP.

Several studies have emphasised that knowledge production is socially, historically, culturally and materially situated (Cicourel, 1990; Lave and Wenger, 1991; Engeström, 1995; Hutchins, 1995; Gherardi, 2000). To understand knowing in practice, we need to go beyond the local level and look at how it is distributed into larger socio-technical networks. As underscored by Nicolini *et al*. (2003: 28) practices 'connect things, people, and events that are distant and only partially congruent, because they allow the coexistence of old and new, because they are able to deal with change and disorder while explaining persistence and order . . .'. At the IVC every CoP is simultaneously part of networks extending well beyond the immediate work context, beyond the department, the institution and even the nation.

Sackett *et al*. (2000) distinguishes between four levels of knowing in medicine, where randomised clinical trials rank highest, whereas descriptive forms of knowing are considered the least trustworthy. As this paper has shown, the nurses and radiographers typically produce the latter form of knowing. They have gradually become participants of their NoP during their professional education and training, and they need to and wish to maintain a certain ongoing relationship to them. The challenge is therefore that the learning needed at the system level to become an integrated whole for the benefit of the patients is rooted in different epistemologies. Moreover, knowledge challenging current practices is more likely to become marginalised, and hence learning processes both within and across the different CoPs may become path-dependent. Hence, '. . . simply fostering links across professions . . . may not result in knowledge integration where the organisational and/or institutional context reinforces separation between the practices of those professionals' (Newell *et al*., 2006: 132). This implies that we had to take into account the material structures within the IVC, the epistemic machineries for knowing in the projects, the influence of professional identity, legal and formal regulations surrounding medical work and division of labour in research.

Even though many breakthroughs in knowledge fail to be translated into change of medical practice (Newell *et al*., 2006), to date little empirical work has taken a practice-based approach to explain these challenges. Knowing is participation in a complex web of relationships among people, activities and material structures (Gherardi *et al*., 1998; Nicolini *et al*., 2003). Knowing is not a static capability, but a practical accomplishment as actors engage in the world (Orlikowski, 2002). The practical implications are therefore that we only get knowledge about a new way of working by practicing it, and if one fails taking into account the networked character of knowing and practicing it may lead to sub-optimal practices. The most important contribution of this paper therefore lies in its descriptions of processes and challenges that may inhibit learning and innovation. To explain these challenges this paper draws the reader's attention to the 'machineries of knowledge production' to explain why learning on the system level of CoPs can be challenging. The present study shows how the networked character of knowing and practicing may lead to path-dependent learning processes: radical change can become limited if the knowledge required by new and radically different practices is incompatible with the existing stock of knowledge. This existing stock of knowledge is, however, not just locally defined, but embedded into epistemic cultures and networks extending beyond the immediate context.

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