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DIGITAL IMAGING USE

Influence of Digitalization on Radiographers´ Work Practice and Knowledge Demands

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Stockholm 2009

Published by Karolinska Institutet. Printed by Universitetsservice US-AB

ISBN 978-91-7409-336-0

To
My father
Filip Fridolfsson

ABSTRACT

The aim: The purpose of this ethnographic study was to show how the radiographer's work practice and knowledge demands change in the transformation from analogue to distributed work.

Method: The study adopts a qualitative ethnographic approach, using participant observation of and semi-structured interviews with radiographers at five Swedish hospitals. In total, 22 radiographers were interviewed and 15 of them were observed. The study classified the radiographers work as follows: 1) *Planning phase* 2) *Performing phase* 3) *Evaluating phase.* To identify properties of knowledge, Blackler's theory of knowledge components was applied.

Results: The study illustrated that the introduction of PACS did not simply entail the transfer of data and information from the analogue world to the digital world, but it also entails new activities, new ways of communicating, new responsibilities and new knowledge demands for the radiographers´. The study also illustrated that the role of the radiographer has changed in three principal areas: 1) Communication in work, 2) Image processing and 3) Image quality assurance, including sending patients home. This led to changes in work practice and the radiographers were called upon to work increasingly independently, and individual practitioners require higher levels of professional expertise. The study also illustrated that radiographers applied different knowledge components in different situations in their image production work. They used *embrained knowledge* when planning X-ray examinations and when viewing and analyzing images. *Encoded knowledge* was required for the use of various kinds of documentation, such as manuals and protocols. *Embodied knowledge* was called for when action was needed or as problem-solving involving "gut feelings". The amount of embrained knowledge increased in the transformation from analogue to distributed work. Some radiographers applied the knowledge components more reflective and some more static.

Overall, radiographers need to have critical and reflective mind in practice – it is not enough to work in an uncritical way. Because work is full of problem-solving action – it is not enough to perform it in an automatic action. The radiographers use the knowledge as routine actors or reflective actors.

Conclusion: The study demonstrated both that the radiographers´ work practice has become more demanding and "highly scientific". Radiographers need more reflective actors in the image production process when working with PACS. Reflective actors are more flexible in their work; there is in the distributed environment little room for static work. In work they needed to analyse images, it was not enough to "check them off"; they cannot just read documents, they needed to interpret them to optimize work performance. In summary, radiographers needed to have a critical and reflective attitude in practice, because work was full of problem-solving action – repetitive automatic action was not enough.

LIST OF PUBLICATIONS

I. The effects of PACS on radiographer's work practice

Larsson W, Aspelin P, Bergquist M, Hillergård K, Jacobsson B,

Lindsköld L, Wallbeg J, Lundberg N. Radiography (2007) 13, 235-240.

II. Use your good judgement - Radiographers´ knowledge in image production work

Larsson W, Lundberg N, Hillergård K. Radiography, accepted for publication Sept 30, 2008.

CONTENTS

1 INTRODUCTION

“I think there is a market in the world for maybe five computers" (Thomas Watson, 1943, IBM's Chairman).

The above quotation shows how difficult it is to predict the future. Today it is obvious that one of the greatest changes in the health care services over decades and in all likelihood the next decades is linked to computers and telecommunications technology. These changes will promote and increase remote monitoring and diagnosis; links between hospitals, between hospitals and general practitioners, between hospitals and clinics. It will speed up the communication and the capacity for remote consultation, operations, and teaching. Linderoth (2002) describes in a study of the implementation of telemedicine in health care, showing that health care work both designed and organized in relation to technical progress (ibid). While Orlikowski (1993) stipulates that the introduction of new technology in itself does not automatically lead to a shift in approach, but there are other factors that are critical as the organization's culture, policies and reward systems.

In this context it is of importance to clarify that the health care is a sector composed of various activities that are dependent on each other in different ways (Öhrming, 1997), where the radiology department has a key role. Radiology has seen one of the quickest technological changes with the global transition from analogue to digital radiology departments (Lundberg, 2000). Initially, the changes in radiology were made in new modalities such as computerized axial tomography, ultrasound and, in a later phase, the implementation of magnetic resonance tomography. During the later part of the 1980s a new technology was introduced: Picture Archiving and Communication System (PACS), which made it possible to digitally manage, transport and communicate images. The technological changes in health care also included people and changes in their work practice (Linderoth, 2002; Lundberg, 2000; Barely, 1986). The people in the technology work practices become users. Löwgren & Stolterman (1998) highlights the risk that technology is viewed as a closed system. Orlikowski (1991) also stress the risk that technology is viewed as an isolated phenomenon and not as an integrated part of work practice*”…it is not surprising that users of a technology often treat it as a closed system or black box” (ibid, pp. 12.).*

The new technology applies quickly as the most natural thing, and the process will not stop.

The new technology requires not only new work routines but also demands of new knowledge for the radiographers (Fridell, 2007). In the context of implementing new technology Orlikowski (1996) describes the importance of the staff's “mental model”

as a crucial element of how new technology is received. She considers that that the staff's focus is based on their experiences and stresses the importance of experience.

Several British studies are focusing on the radiographers´ "new" reporting activity working with PACS (Brealey, et al. 2005; Paterson, Price, Thomas & Nuttal, 2004; Brealey & Scally 2008). However, to the best of my knowledge there are no previous studies that illustrate the impact of digitalization on the knowledge demands of the radiographers. Such studies require knowledge of radiographers´ work activities and how they use their knowledge in these activities. "The purpose of this study is to identify, analyse and describe how radiographers´ work practice and knowledge demands have been changed in the transformation from an analogue to a digital environment". The reasons why the focus has not been on radiographer's knowledge may be that digitalization has been conducted quite recently and that knowledge is "hidden" in work. Such studies call for qualitative studies which are rarer within medicine.

While working as a radiographer both in clinical practice and in the education, the change in the profession's work practice has always been intriguing. This initiated my research work. Hopefully this thesis can contribute to the understanding of the role and knowledge demands of the radiographers.

The remainder of the paper is organized as follows. As explained above, Section 1 is the introduction and Section 2 presents the aim of thesis. Section 3 describes the radiological services, radiological techniques and a description of knowledge and knowing, research by means of the impact of PACS on radiological work, knowledge required in health care and in radiological work and ethnography in health care. In Section 4, Blackler's knowledge organization theory is presented. In Section 5, the ethnographic method is applied and material and analysis is described, and this section also presents ethical considerations. Section 6 the results, Section 7 contains the discussion and Section 8 finally explains what conclusions are drawn and future work.

2 THE AIM OF THE STUDY

The aim of this study is to identify, analyse and describe how radiographers´ work practice and knowledge demands changes in the transformation from an analogue to a digital environment at five radiology departments in Sweden.

In order to add to the understanding of the experienced effects that that radiographers have in the transformation from analogue to digital environment a background of the radiological service, the radiological technologies applied, knowledge and knowing. Knowledge and knowing is presented as these are components needed to perform radiographic work. I will therefore briefly describe this in this section.

3 BACKGROUND

This section provides a brief description of the radiological service, radiological techniques surrounding the empirical research i.e., the radiology departments in Sweden, and in particular the systems applied is described, and knowledge and knowing.

3.1 RADIOLOGICAL SERVICE

Radiology departments are service units for all kinds of clinical departments within health care. Their services are offered inside the hospital, to other hospitals, to primary care units and to general practitioners. The radiology services comprise diagnostic reports to the referral physician and patient interventions. The radiology departments are university, regional or local hospitals or at primary care centres. They are managed in Sweden by the public health service and county councils or by private providers. In total, there are about 145 radiology departments in Sweden. The smaller radiology departments each perform about 20 000 examinations per year, while radiology departments at the university hospitals perform more than 200 000 examinations per year on average. The different types of radiological examinations offered by large radiology departments in Sweden are: skeletal, chest, mammography, ultrasound, gastrointestinal, urinary tract, computer tomography (CT), magnetic resonance tomography (MRT), vascular examinations and therapeutic interventions.

Conventional lung examinations and computer tomography examinations of the brain are the most common form of X-ray examinations. In Sweden there are 3 050 licensed radiographers working in the health care system (Sveriges Kommuner och Landsting, 2007). The radiology department is a highly technical environment. Sophisticated equipment for technical examination is used to diagnose injury or disease and for patient interventions (Ballinger & Frank, 2003).

It is obvious that radiographers play an essential role in the production of a diagnosis and in the process of treating patients who are ill or injured (Larsson et al, 2007). Work at radiology departments is highly structured, production oriented, complex, distributed and technical (Lundberg, 2000). A more detailed description of the technique is provided in the next subsection.

3.2 RADIOLOGICAL TECHNIQUES

X-ray radiation was discovered in late 1895 by Wilhelm Conrad Röntgen. In 1901 he was awarded the Nobel Prize for his work. Röntgen realized that one of the properties of X-ray radiation was its ability to darken photographic film. When X-rays are projected through a patient, the X-ray reveals the shadows of objects that X-rays are unable to penetrate, like bones or metal objects, on sensitive film (Isaksson, 2002). This is the process of producing film which will be referred to in this thesis as the

analogue method. This technique was used by the majority of radiology departments in Sweden until the 1990s.

The introduction of the digital techniques includes both computed radiography (CR) and direct radiography (DR). CR was the transfer from X-ray films to digital image plates. Image plates collect X-ray radiation and transfer it to a computer, creating digital images. Although the image, through CR, was in a digital state it was nonetheless transferred to a photographic film. According to Huang (2004), the reason for this was the lack of technological solutions for storing and communicating digital images, e.g. limits posed by the picture archiving communication system (PACS). When PACS improved and large volumes of images could be stored and communicated on a local network, a new technology emerged, DR. Both CR and DR are digital techniques; the difference is that CR produces digital images through digital plates whereas DR produces them through digital detectors implemented directly in the modalities. The DR technique applied digital detectors inside the modality producing digital images that could be stored directly in the PACS. Direct storage of images into the PACS system made it easier to handle, distribute and communicate images in gigantic quantities (Buchberg, Seibert & Leidholdt, 2002).

New techniques to produce radiology images have been developed over time, e.g. ultrasound, computer tomography (CT) and magnetic resonance tomography (MRT). The pioneers in the application of gynaecological ultrasound date from the 1960s. This technique underwent explosive growth in the mid-1970s and is still a common technique applied in radiology today. The ultrasound technique itself is built on high-frequency sound waves producing digital images. Ultrasound has traditionally captured “real-time” images, illustrating the structure and movement of the body's internal organs, as well as blood flowing through blood vessels. However, recent innovations related to this technology have enabled storage of the ultrasound film, making it possible to display ultrasound images without the patient being present.

Since 1970, the CT technique has been successfully applied within medicine. The CT technique uses X-ray equipment to produce multiple images of the inside of the body. Thereafter it uses a computer to join the images together in a cross-sectional view. CT systems consist of two main parts, namely a physical measuring technique and a mathematical reconstruction algorithm, which calculates the local concentrations from the raw data obtained.

MRT has been used since the late 1980s and is based on the use of magnetic field and radio frequencies to produce multiple images. The objective of magnetic resonance studies of human tissues has predominantly been to examine tissues that have water molecules which contain a lot of protons (Dussauge, 2008).

A description of the systems is provided in the next subsection.

3.3 RIS, MODALITIES AND PACS

Radiological information systems (RIS) have been used in Sweden for over 20 years. A RIS is used for administrative purposes, and includes functions for patient data, digital request, registration, scheduling radiological examinations, and creating reports. Prior to the RIS, the radiology department used paper documents for these purposes. One key document was the paper request created manually by the referring physician. The request includes data such as the patients' name and date of birth, and name of the clinician requesting the examination, the type of the examination required, the patient's case history, and sometimes the clinician's preliminary diagnosis. Another document was the paper booking schedule for patients. In Sweden, all radiology departments have implemented a RIS for the documentation of the radiological service. However, sometimes the request is sent as a paper document from the clinician to the radiology department reception. Then it will be scanned to a digital format. To complete the examination radiographers work with the *modality systems*. The modality is a computer system also including the X-ray/MRI/-Ultrasound/etc. machine. The modality systems have a reading unit. When the modality for producing images related to an examination is set up, the images "to be produced" are also linked to the RIS data already registered for the patient. When radiographers apply the functions in the reading unit, they view the images to see if they seem to be acceptable for diagnosis.

This check is followed by a final check of the image quality, which is performed by the radiographers on the quality control unit of the modalities (sometimes the *PACS*). If quality is poor, a further image process can be conducted by the radiographers at the quality control unit. When the examination is completed, that is, a final quality check has been performed, the images are sent from the quality control unit to the PACS. PACS is a digital communication system described in more detail by Müller, Michoux, Bandon & Geissbuhler (2004) as a system for electronic storage, retrieval, distribution, communication, display, and processing of medical imaging data. RIS is also closely related to the electronic patient record (EPR), which is used as the main system for tracking patients throughout the hospital via a unique master patient record number. RIS is also connected to modalities as the 'camera' where the image taken has its own computer system to control the machine, how the image should be exposed, and the level of radiation to be used (Fig. 1).

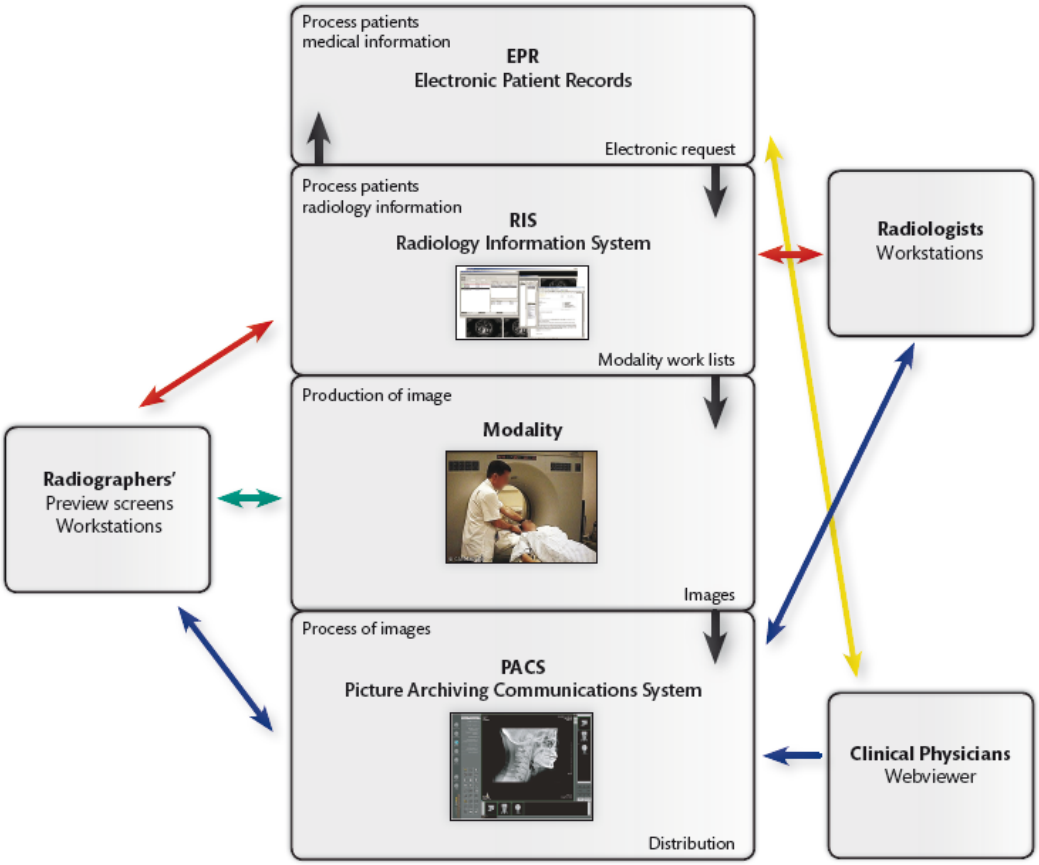

Fig. 1. Digital radiological environment.

3.4 KNOWLEDGE AND KNOWING

A growing amount of literature argues that a broader approach to the knowledge concept is needed. This implies relating knowledge to practice or to something people do (Blackler, 1995; Brown and Duguid 1991; Czarniawska 1997; Knorr-Cetina 1999). Blacker (1995 p.1029) observes that the contexts of the terms *knowing* and *knowledge* are "…multifaceted and complex, being both situated and abstract, implicit and explicit, distributed and individual, physical and mental, developing and static, verbal and encoded". He argues that knowledge companies, such as those involved in health care, include individuals characterized by being: frequent problem solvers; creative; high reliance of individuals; high levels of education; and a high degree of professionalism.

A classic reference in the field of knowledge is the work of Nonaka and Takeuchi (1995). Their theoretical thinking is based on the distinction between tacit and explicit knowledge. They define tacit knowledge in the context of something people do without thinking about how they do it, and they give the example of knowledge based on intuition. They define explicit knowledge or codified knowledge as knowledge that can be articulated in formal language including grammatical statements, mathematical expressions, specifications, and manuals (ibid).

Cunliffe and Shotter (2006) look at knowledge as something that can be expressed and claim that there is no knowledge, or reality, beyond our own experiences. An applicable description of how to present and understand knowledge is presented by Ryle (1949) who emphasizes the differentiation of *knowing that* and *knowing how*. An example of the *"knowing that"* type of knowledge in health care is when a nurse uses theoretical thinking, while nurses use their *"knowing how"* knowledge when they give an injection.

Knowing is something that occurs in practice (Orlikowski 2002 & Wenger, 1998). According to Schön (1983 pp. 49) "Our knowing is ordinarily tacit, implicit in our patterns of action and in our feel for the stuff with which we are dealing". Maturana and Varela (1998 pp.26) emphasize that "All doing is knowing, and all knowing is doing". This approach to knowing coincides well with Orlikowski's claim: "An explanation grounded in what it is people do every day to get their work done" (2002 pp. 249). Cook & Seely Brown, 1999, adopts a similar perspective of knowing in their statement: "We act within a social and physical world and since knowing is an aspect of action it is about interaction with that world" (ibid pp. 388). Furthermore, they argue for "knowing" as something that is a part of action, not something that is used in action or necessary to action. Cook & Seely Brown (1999 pp. 387) conclude that "knowing is dynamic, concrete and relational".

3.5 RELATED RESEARCH

Research that focuses on PACS impact on radiological work and knowledge required in health care and in radiological work, preferably involving ethnographic methods, is presented as the related research in this section.

3.5.1 The impact of PACS on radiological work

Lundberg (2000) described how the implementation of PACS influenced not only the technology but also the staff and their work routines. Pilling (2003) studied PACS from another perspective, that of the users, and concluded that PACS has been accepted well by a wide cross section of hospital staff. It has improved their working lives and made a major contribution to the working of the hospital as a whole.

According to a study by Mac Vicar (2005), the installation of PACS should be viewed as an opportunity to improve the working environment. This is an ergonomic study – how do people work in the digitized environment?

Several studies have explored the effects of PACS on workflow; for example, Redfern et al. (2000) evaluated changes in the elapsed time from the examination request until the image is dispatched to the radiologist, and from dispatch until report dictation. PACS slowed technologists by prolonging the quality-control procedure, and the radiologists' workflow was shortened or not affected. This contrasted with the findings of Langen, Bielmeier, Wittenberg, Selbach, & Feustel (2003) regarding the temporal changes of the workflow caused by digitalization of the radiology

department. Compared to conventional film-screen systems, complete digitalization of a radiology department was time saving at nearly all steps of the workflow, with expected positive effects on the entire workflow quality (ibid).

Other studies have described the people and even the individuals related to PACS: Knepper (2007) focuses on changes associated with PACS. He emphasizes that it is essential to have a policy for making changes to the information system, that it is important to include studies in changes to workflows such as the distribution of images, network settings, monitor settings and locations of workstations. Bramson & Bramson (2005) highlighted the importance of focusing on how people work as a consequence of changing to PACS. Cohen, Rumreich, Garriot & Jennings (2005) write that in order for PACS to be a successful project "cultural" changes at the individual's level are required.

Studies were also focused on the change in the radiographers´ role: Brown (2004) states that the role of radiographers has changed, as the demand for radiography services has increased markedly and the work of radiographers has become more complex. Fridell (2007) focuses on the radiologist and on the radiographer's changed professional role in the transition from an analogue to a digital environment. Initially the radiologists felt secure in using the analogue technology. Analogue films were tangible. Digital images could be manipulated. The radiologist felt uncertain as to when the manipulation of images was optimal. This uncertainty decreased over time. Radiographers then saw a great potential in the introduction of new routines using PACS. Crowe and Sim (2004) have studied the effect of the ready availability of radiology results on clinicians, clinical decision making and the time taken to treat patients at a large teaching hospital in Brisbane. This study showed that the introduction of RIS/PACS has been well received by senior clinicians and it has been helpful in clinical decision making. Patient management has been improved and the time taken to arrive at clinical decisions has been reduced, particularly in neurosurgery. The RIS/PACS has significantly improved access to imaging resources for teaching, owing to the ability to retrieve reference images and to project high-quality images during teaching sessions. White & McKay (2002) asserted that if radiographers were to develop their roles, they needed to continue providing a high quality service and demonstrating high-level competencies, skills and knowledge.

Brealey et al. (2005) compared reporting by radiologists and radiographers and Paterson et al. (2004) studied reporting by radiographers with the aim of developing a practice guide. Brealey et al. (2005) also compared radiographers´ interpretation to reference standards. This study systematically synthesizes the literature to provide an evidence base showing that radiographers can accurately report plain radiographs in clinical practice.

3.5.2 Knowledge required in health care and in radiological work

Aanestad, Mörk, Grisot & Hanseth (2003) have critically studied how knowledge production and knowledge traditions may be an obstacle to learning. The paper builds on the notion of "Communities of Practice" where knowledge was seen as a socially created and shared resource. Clinical work in hospitals properly illustrates the problem area of the knowledge traditions, where several different professions with different methods meet and collaborate. In such situations, learning processes need to be re-examined. The paper argued for a wider view of knowledge. Smith, Goodwin, Mort & Pope, (2003) described and explored how different types of knowledge are learned and used in anaesthetic practice from another perspective. The conclusion from this study was that the expertise is acquired by working with colleagues and by working independently to develop personal routines. The routines themselves mark the successful incorporation of new knowledge but also function as a defence against the inherent uncertainty of anaesthetic practice.

The subsequent studies focused on radiographers´ evidence-based knowledge in work practice: Hardy & Snaith (2007) discuss the relationship between radiographers´ practice and using evidence from other health professionals. This paper discusses the terms 'extension' and 'advancement' in relation to radiography practice and, using evidence from the debates of other health professions, attempts to offer some clarity to the terminology, presenting one interpretation of its possible application to the radiographer role in the United Kingdom.

Upton & Upton (2006) discuss knowledge and use of evidence-based radiographic practice. Differences were noted between individual professional groups. For example, podiatrists, radiographers, and orthoptists reported having less knowledge of clinical effectiveness (CE) and evidence-based practice (EBP) than physiotherapists, occupational therapists, dietitians, speech and language therapists, and psychologists. Barriers to implementing EBP were similar for all groups, with lack of both time and money cited as the main issues (ibid). Ebrahim (2005) studied the research activities, knowledge and approaches to EBP of radiographers. It was concluded that the respondents' knowledge about EBP was poor, but there was evidence of communication elements of EBP (ibid). Brealey & Scally (2001) assert that systematic reviews of research evidence can help to assimilate a knowledge base by ordering and evaluating the available evidence on the reporting accuracy of different professional groups (ibid).

Davenport & Prusak (1998) describe three pitfalls related to how knowledge is managed and applied. The first is that the information about where to find knowledge is often incomplete. This makes it difficult to find the knowledge, if it can be found at all. In the radiology department it can be difficult to find the knowledge because of the fast changes such as new image techniques or new numbers of images. The second is that the same knowledge resides in many different places and at different levels of detail. This makes it difficult to know which source is the most suitable one.

An example is when changes in the image production have been made; the various personnel categories may have received the information at different times and in different ways, and then they probably understand and interpret the information in different ways. The third is that people would rather ask a person in the office next door than try to find someone elsewhere in the organization that may be better suited to answer the question. To ask people next door is an obvious tendency in health care, in connection with efficiency and time pressure. In a study of collaboration within a research environment, Kraut, Egido & Galegher (in Groth, 1999) found that researchers who have offices next door to each other communicate approximately twice as much as those whose offices are on the same floor, but located further apart. They also argue that although one explanation is that people with interests in common often are located close to each other, people are more likely to get acquainted and to identify shared interests if they get the opportunity to meet. This is likely to occur around the lunch table, in a corridor, etc (ibid). According to Groth, (1999) illustrates this importance of the location in communication with other people. It is not only important to be located in offices nearby but also to get the opportunity to meet occasionally.

Decker & Iphofens (2005) explore the potential role of oral history research as a tool for the development of knowledge about the practice of radiography. The studies above show how PACS influence radiological work in different ways. These include work routines, how people work, and people's acceptance of PACS, the effects on the organization, the radiographers´ changing professional role, and even their reporting role. The studies also illustrate the complexity of knowledge in health care work generally, and more specifically in radiological work. Finally, they show that the ethnography research method is useful in relation to health care issues in different ways (Savage, 2000). However, detailed analysis of the distribution of changes in radiographers´ duties and the influence of PACS on the radiographers´ knowledge was found to be sparse.

3.6 ETHNOGRAPHY IN HEALTH CARE

Ethnographic research method has become useful in understanding the organization of health care (Barley, 1986; Crowe & Sim, 2004; Karasti, 1998; Lundberg; 2000 & Smith et al. 2003). The method can provide a nuanced understanding of an organization and allow comparison between what people say and what they do. For example, Barley (1986) used the ethnographic method in observing the impact of CT technology on the social order of two Boston radiology departments. He witnessed the evolution of work relationships as technology was incorporated into the work flow of the hospital. Barley codified the interaction between radiologist and technician and he demonstrated that the behaviour between radiologists and technicians changed significantly due to the interpretive challenges of the new equipment. Atkinson (in Savage, 2000) used an ethnographic approach to study the clinical reasoning in a group of physicians through observing grand rounds and clinical lectures. He showed how the expert knowledge of these physicians emerged

as a local and joint production through clinical talk that was simultaneously characterized by confidence, dogmatism, and uncertainty. From this, Atkinson raised important issues about the use of algorithms and decision-making models within medicine and whether these acknowledge the complexities of practical work and clinical reasoning. Fry (2004) presented an ethnographic study intended to provide insight and understanding needed to educate and support the triage nursing role in emergency departments. To accomplish their role and maintain the rhythm of care triage nurses used three processes: gate-keeping, time-keeping and decision-making. When patient overcrowding occurred, the three processes enabled triage nurses to implement a range of practices to restore the cadence of care to which they were culturally oriented. The findings provide a framework that offers new ways of considering triage nursing practice, educational programmes, policy development and future research.

4 THEORY

To enhance the interpretation of the knowledge demands of the work, Blackler's (1995) theory of the knowledge organization has been chosen. The theory is built on the theory of knowledge in work practice proposed by Collins (1993), who describes four kinds of knowledge: embrained knowledge, symbol-type-knowledge, embodied knowledge and encultured knowledge. In contrast to Collins (1993), Blackler uses the component encoded knowledge (which includes some interpretation) instead of symbol-type-knowledge and adds the component embedded knowledge to Collins's four types of knowledge. Blackler's theory outlines five components of knowledge: embrained, encoded, embodied, encultured and embedded knowledge. He also points out that we not shall see the different forms of knowledge as separate and his division between the components is not completely clear (ibid).

Blackler (1995) described embrained knowledge as something that depends on people's conceptual skills and cognitive abilities. The knowledge is formal, abstract or theoretical. Encoded knowledge is conveyed by signs and symbols represented textually and digitally de-contextualized. It is knowledge that has been coded and stored in blueprints, recipes, written rules and procedures. It is public knowledge accessible to the wider organization and can be understood and used without a knowing subject. Embodied knowledge is described as action-oriented and context-specific. Encultured knowledge is stored in the culture. This kind of knowledge is embedded mostly in the language. Embedded knowledge is upheld because of routines and doing things in a repeated way without thinking.

Further on, Blackler discusses knowledge in relation to work and through these components he makes the knowledge process in complex organizations visible. He further underscores that the implication is that not only limited groups are regarded as knowledge workers, but that all individuals and all organizations are knowledgeable (Blackler, 1995). Three of Blackler's knowledge theory components have been chosen for use here: 1) embrained knowledge, 2) encoded knowledge and 3) embodied knowledge. These components have been chosen because they allow us to be specific about knowledge demands and describe in more detail radiographers´ use of cognitive knowledge, how they use guidelines, and how they use their practice knowledge in the image production process. It was obvious that the radiographers used embrained knowledge when they were planning their duties and when they were viewing images. They were using encoded knowledge when they were using manuals, documents and protocols, etc., in different situations such as processing images. When they were processing images, they also used embodied knowledge.

4.1.1 Criticism of Blackler's theory

One criticism may be that the classification of knowledge types is very theoretical; in practice, various kinds of knowledge are not intersperse and not applied in the categorical way that Blackler describes. The use of knowledge types *overlaps in practice.* This makes it harder to say with certainty that one kind of knowledge is more central than another. The situation and knowledge demands needed in radiographic work may change quickly: for example, a patient's condition may suddenly worsen dramatically, requiring a shift from one knowledge demand to another. How to handle these *shifts of* knowledge is another aspect that is not discussed by Blackler.

In this study, two of Blackler's categories were excluded: encultured knowledge and embedded knowledge. The reasons for this were that it was difficult to identify the difference between the two when interpreting them in practice, and that these categories were outside the scope of this thesis.

In summary, the criticism is that there are some uncertainties when applying Blackler's theories in real-life situations.

5 METHOD - ETHNOGRAPHY

Ethnography is, typically small-scale social research carried out in everyday settings, using a range of methods to focus on the meanings of individuals' actions and explanations rather than their quantification (Savage, 2000). The ethnographic method originates in anthropology and ethnology. The word *anthropology* comes from Greek, and means the study of humans. The word *ethnology* also stems from Greek and refers to the study of human racial groups and nations. *Ethno* means nation and *graphy* means description, meaning the description of human nations. Ethnography became the tools and principles anthropologists and ethnologists used for systematically gathering, processing and analyzing collected and produced material. Anthropology focused on the origin of humans, while the emergence and evolution of cultures fell under ethnology. The close of the nineteenth century brought with it a growing interest in methodological issues, and ethnography became the methodological tool for anthropologists (Hammersley, 1992). Hoobs & May explained in Pilhammar Andersson (1996) that ethnography is viewed as an application that is most effective for gathering silent knowledge about general practice. Ethnography is often portrayed as a richer, more detailed form of data collection than the traditional structured interview. According to Patel & Davidson (1994), empirical qualitative research, e.g. ethnography, is distinguished by the fact that the perception of an individual is that person's reality. Interviews in ethnographical research differ from spontaneous and informal conversations in places that are actually intended for other purposes. A researcher who wants to conduct an ethnographical interview must remember not to steer the interview in a way that causes the informant to say what the researcher wants to hear. Instead, the researcher must ask open-ended questions to allow the interviewee to independently expand her response as she desires (ibid). Encourage the informant to say a bit more and explain what she means. What distinguishes an ethnographical interview from other types of interviews is that the questions are often not decided when the interview begins. The ethnologist has an approximate understanding of what topics will be addressed but does not know exactly what the questions are or when they will be asked. Open-ended questions that allow the interviewee to broaden her response are common. This allows the interviewee to speak freely, using her own words, within the framework of the topic. The discussions become more flexible and many times flow more freely and naturally (Hammersley & Atkinson, 1995).

In order to understand human behaviour, researchers need to approach the individual in a way that gives the researcher an understanding of the individual's behaviour. Different cultures have different rules; ethnographic research often focuses on these rules of behaviour (Hammersley & Atkinson, 1995). The researcher can learn about the culture she is studying as a participant observer and will then come to perceive the world in the same way as the people she studies, thereby learning to understand their actions. Learning about the culture of the people being studied is important if the researcher wants to know not only what they do but also why they do it in a

particular way (ibid). It is important that researchers are aware that study objects can behave in a way that they believe the researcher expects.

The aim is to attain a picture of the phenomena of the study which makes sense. From here, more general theories may be developed (Merry, Davies & Maltby, 2000).

5.1 ETHNOGRAPHIC METHODS APPLIED

Among the ethnographic methods interviews and observations were the chosen methods of data collection since the purpose of this project was to identify and analyze which qualifications were in demand and to describe the radiographers´ work method in terms of both analogue and digital activities. The main data collection for these studies was interviews. The interviews reflect the radiographers´ own description of the activities. The interviews were open-ended, which means that the interviewer uses topics that steer the interview, and semi-structured, which means that the informants are asked similar questions within the selected topics. The answers obtained were followed up by other questions depending on what topics had to be elucidated further. The interviewers created a follow up question. This is an appropriate strategy in contexts where standard questions cannot be drawn up ahead of time because not enough is known about the situation under investigation to do so (Jordan & Yeomans, 1995). But all interviewees in the study were asked similar questions, covering the same areas, though they were not always phrased identically, depending on the course of the conversation.

The following areas were covered in the interviews: 1) the transformation from analogue to digital, 2) changes in the radiographic profession, 3) the knowledge area. The questions asked included, for example: Who do you communicate with at work? How is this communication conducted? How has work practice changed during the transformation from analogue to digital work? What differences can you identify in the work? How do you know what to do? To what extent is computer-supported communication applied? Can you describe your professional role? What kind of knowledge is most important in practice?

In participant observations, the researcher describes an event or a process in which she has insight (Ejvegård, 1993). The observation enables empirical observations of natural situations. Bailey (in Cohen and Manion, 1989) emphasizes that the observation method has special advantages compared to other methods since it allows the researcher to study non-verbal behaviour and observe an event while in progress (ibid). The observations in this study were made by following the path of an examination request from initiation to sending images to PACS as well as sending the patient home. By using different methods, it is possible to integrate the results from each data collection method. Bergquist and Lundberg (2000) point out that the combination of ethnographical research methods makes it possible to focus on both the details and the overall context. The purpose of using observations in this study

was both to confirm what had been identified in the interviews and to enhance the understanding of how activities were related in time and space. An ethnographic study which has inspired us was a study which described and explored how different types of knowledge are acquired and used in anaesthetics practice (Smith et al., 2003). This study by Smith et al. (2003) was done through observations and semi-structured interviews with anaesthetics staff in two English hospitals.

In the present study the interviews and observations were carried out in the following way:

5.1.1 Interviews

- Participation was voluntary.
- The informants were contacted via email or telephone calls. They received concise information about the study in general and the purpose of the interview.
- They were also informed about the question areas and which aspects would be observed. They also received a time schedule. Furthermore, the confidentiality of the study was highlighted.
- The interviews lasted from 30 minutes to two hours.
- All interviews were recorded on a tape recorder, transcribed, and then confirmed by the person interviewed.
- The informants were invited to a separate room at the clinic in question.

5.1.2 Observations

- Participation was voluntary.
- The participation received information why the observations were important.
- The radiographer confirmed their willingness to participate in the beginning of every observation
- The observations were performed without audio or video recording.
- The observers were placed at the control room which gave a general view of the radiographers´ image production work and the observers have a “fly on the wall” approach.
- Each radiographer was observed for two hours. In total, the radiographers were observed for 30 hours.
- In addition, departmental audit meetings and teaching sessions were observed.
- Detailed notes were taken during the observation period, and transcribed immediately afterwards.

5.2 CRITICISM OF ETHNOGRAPHY

The ethnographic method used is unfamiliar to many people working in radiography and may raise a number of questions. It is mainly based on participant observations, observations and open-ended as well as unstructured interviews. One of the disadvantages of ethnographic researches it that it takes a lot longer than most other kinds of research (Myers, 1999). Not only does it take a long time to do the fieldwork, but it also takes a long time to analyze the material and to transcribe it from tape to digital computed format. Another disadvantage of ethnographic research is that it does not have much breadth, although it has a great depth. Unlike survey, an ethnographer usually studies just the one organization or the culture. In fact this limitation is a common criticism of ethnographic research – which it leads to in-depth knowledge only of particular contexts and situation (Silverman, 1997; Van Maanen, 1988).

5.2.1 Material

In the following section, the radiology departments and the number of radiographers included in the study are presented (Table I). The empirical fieldwork began in October 2003 and finished in 2007. The sites chosen were three university hospitals digitized between 2002 until 2006 (A, B, C), one region hospital digitized in 2003 (D) and one local hospital digitized in 2003 (E). During this period, a total of 22 radiographers were interviewed at five sites (Table I). These five sites were chosen because they had purchased the PACS technology by the time that this study started and due to traditional contacts from previous cooperation. The sample satisfied several criteria, such as representing the population through the inclusion of both academic and community hospitals of varying size, location mostly in the area of Stockholm but also in the south of Sweden, adoption of the digital technology, and willingness to participate in the study.

In total, 22 radiographers were interviewed and 15 of them were observed. Four radiographers were interviewed and two were observed at hospital A, eight radiographers were interviewed and four were observed at hospital B, four radiographers were interviewed and three were observed at hospital C, three radiographers were interviewed and observed at hospital D and three radiographers were interviewed and observed at hospital E (Table I).

Table I. Illustrating the sites, number of radiographers, years of experience and clinical instructors involved in the study.

Sites	Radiographers interviewed for paper 1	Additional interviews (for paper 2)	Observations (for paper 1)	Worked as radiographer ≤ 5 years	Worked as radiographer 6 to 10 years	Worked as radiographer 10 ≥ years	Special titles such as clinical instructors, etc
A	2	2	2		2	2	2
B	4	4	4	1	2	5	4
C	3	1	3		1	3	1
D	3	0	3	1	1	2	
E	3	0	3	1		1	
Total	**15**	**7**	**15**	**3**	**6**	**13**	**7**

5.2.2 Selection Process

The inclusion criteria were that the departments had varying experience of PACS, varying professional experience and one major academic analogue working department. The choice of the sites for the empirical work was based on the fact that they were among the Swedish institutions that had used PACS for a period as well as and even one analogue department. So who should be interviewed? Hammersely & Atkinson (1995) state that sometimes this question resolves itself; some people want to talk. The idea is to find people with the desired qualifications who appear willing to share information and their experience with the ethnologist (ibid). In this study, the local head nurse was the person who chose the informants.

5.2.3 Analysis

In an ethnographic study, analysis is done continuously. Text material is processed and recorded interviews and other texts are regularly transcribed throughout the analysis phase. Regular analysis can provide ideas on how to proceed. In this way, new and unexpected information can enrich the study. It is also an advantage to start the analysis process while the interviews are fresh in the mind of the researcher (Patel & Davidsson, 1994). After initial reading of the material, the writers categorize the material (Kvale, 1997). After repeatedly reading through the original texts and the researcher's own updated notes, patterns, themes and categories begin to emerge, making it necessary to process and sort the original text (Patel & Davidsson, 1994). After defining a few concrete and analytical categories for organizing the data, the next phase begins, namely clarifying the meaning of all the gathered data (Hammersley & Atkinson, 1995).

Sandelowski (1993) argued that issues of validity in qualitative studies should be linked not to 'truth' or 'value' as they are for the positivists, but rather to 'trustworthiness', whereby the scientist is viewed as having made those practices visible. Trustworthiness has been further divided into credibility, which summarize how well the observations agree with the results. The observations in this study agree well with the results depending on the detailed content analyses process on the basis of Polit & Beck (2004) and even because the researchers are trained to think reflexively and for some observations using two researchers helped to further check this aspect and produced similar accounts. Transferability, summarize if any generalizations to other milieus is possible (Graneheim & Lundman, 2003; Lincoln & Guba 1985). It seems that this qualitative analysis is transferable to other similar radiology settings and even to other settings as e.g. midwifery working with ultrasound.

This study has a quick and dirty ethnographic approach which is one of the ethnographic methods. Hughes et al. (1995) describe that quick and dirty ethnography can yield valuable knowledge of the social organization. It is built on a qualitative analysis method focused on establishing meaning and interpretation of radiographers´ image production work. When questions arose during the analysis of the material, a number of additional telephone calls were made for clarifications of the interview

statements, and notes were taken during these calls. The analysis began with reading and annotating the transcripts to identify themes in the transcript, through content analysis. Polit & Beck (2004) define content analysis as "the process of organizing and integrating narrative, qualitative information according to emerging themes and concepts" (p. 714). Graneheim & Lundman (2003) describe content analysis as a common method to condense the data while still capturing the essence of the descriptions (ibid). The interviews and observation notes were read several times. To enhance the interpretation of the changes in radiographers´ work practice from analogue to digital technology, three themes were identified in the analysis process: 1) Planning phase, 2) Performing phase 3) Evaluation phase. Those themes were chosen because the radiographers work with all three phases both in the analogue and in the digitized environment.

The material from the interviews was collected and divided and analyzed as follows. This was done by:
Firstly, separating the material according to the various **work phases** e.g. 1) Planning phase, 2) Performing phase 3) Evaluation phase for every interviewed person. The overall questions were focusing on the radiographer's work practice and knowledge demands in work e.g. the process from when the radiological examination is planned to the point where the images are produced and accessible on the PACS.
Secondly, the material in the various areas was analyzed according to the phases. The sentences were here reduced to words or **phrases**.
Thirdly, the material was **condensed** so that word or phrases with the same context were excluded.
Fourthly, the remaining words or phrases were sorted into the **groups** that have developed during the analysis.
Next analysis was undertaken to examine patterns and determine purposeful underlying meanings. At this stage related codes were analyzed to find or identify **concepts** that were typical for the result from the interviews.

Table II. Examples of the analysis process.

Work Phase	Phrase	Condensation	Groups	Concepts
Planning phase	*"I check what is to be examined, and compare data in the request with the booking"*	Needed control Embrained knowledge	Structure work	Routine actor
Evaluation phase	*"I want to look at the spine frontal to know which side the patient should lie on when I move on and take the lateral projection"*	Deep understanding Embrained knowledge	Analyse images	Reflective actor

5.2.4 Ethical Considerations

In order to arrive at results in this study, the researcher must have access to the informant's experiences. This trust is delicate and sustaining this trust requires constant nurture and confirmation (Eliasson, 1995). Hermerén (1996) points out four principle requirements to protect against injury, offence or unpleasantness for those participating in the research project - to which the researcher in this study has conformed. Firstly, there is the need for openness, which means that the researcher should explain the activities in such a way that those participating in the study have sufficient knowledge to give their consent to participate. The second is the need for self-determination, which means that the researcher should not exercise any pressure on the informants and they cannot be in a position where they are dependent on the researcher. The third is the need for confidentiality, which means that the identity of those participating in the research project is to be protected. The informants in this study cannot be identified. The fourth is the need for autonomy, which means that the data collected for research may only be used for this purpose (ibid). The information provided to the informants in this study is based on all of these requirements.

6 RESULTS

The result section is based on two articles. Supplement 1 focuses on radiographer's changes in work practice and Supplement 2 focuses on changes in knowledge with regard to radiographers translating from an analogue to digital working department. I will give a separate account of each article, with the aim of presenting the different changes, after which I will suggest and discuss, in general, how the changes in knowledge demands may be met and supported by university programmes in radiography and radiology departments. The focus for this discussion is how the changes in work practice have affected the changes in knowledge demands and what trends in changes this may lead to in the future. One can see from the results, Table III, that planning work has not been affected by the change in technology. However, the performance phase, where films are produced in a developing machine and images are produced and sent to a quality workstation for check-up, has been affected. In the evaluating phase there are obvious changes, with radiographers checking image quality and sending patients home.

To understand and describe the interplay between humans and technology in order to understand work practice and knowledge changes is a challenge. Doubtless an important component in work practice is the technology in use. This technology is not an isolated factor in work, but an integrated component influencing where to act, who to act with, how to act, and what knowledge is needed to act. Technology shapes its environment just as the environment also shapes the technology. Changes take place when a new technology is introduced into an organization. How individuals handle these changes represents important information for the understanding of the outcome of the introduction of a new PACS technology. We have analysed and compared both work practice and knowledge changes in order to find out whether there were any significant changes or new knowledge demands in the PACS work process.

Prior to planning work at the radiology department the request, from another unit/doctor, is sent to the radiology department. The first step is to book an appointment for the examination. The patient is scheduled and registered in RIS, also in the analogue environment. Previous examinations and reports are retrieved from the digital archive for review and to facilitate planning of the new examination. Correspondingly, in the analogue environment, previous X-ray films and requests are pulled from the analogue archive for the same purposes. When the patient arrives at the department she is shown to the laboratory by the assistant nurse or the radiographer.

In this research, empirical studies of conventional and PACS-based radiographic work practice were performed in order to identify changes in radiographers´ work practice and changed knowledge demands. This is important for the result of the work, both at the individual and at the organizational level. The changes in radiographers´ work practice are presented in Table III and the changes in radiographer's knowledge demands are presented in Table IV.

The results are illustrated by classifying radiographic work into 1) the *planning phase* in which the preparation for the film/image production is made; 2) the *performing phase*, which is the actual film/image production activity when the patient is positioned for the examination in the radiology laboratory; and 3) the *evaluating phase*, which is the completion of films/images e.g. quality check of films/images and sending patients home.

Table III: The changes in radiographers´ work practice in the transition from an analogue to a digital environment, with regard to skeletal examinations.

ANALOGUE ENVIRONMENT	DIGITAL ENVIRONMENT
PLANNING PHASE	
Use paper documents and films	*Use digital text and images, dynamic interaction*
Reads the paper request	*No change*
PERFORMING PHASE	
Use film cassettes	*Use digital image plate or direct digital technique*
- *Set kilovolt and milliampere parameters* - *It is very important that the exposure data is properly set by the radiographer*	- *Set kilovolt and milliampere parameters* - *Automatic settings of exposure control and wider latitude. If manual settings are used anyway for these parameters less accuracy is needed due to wider latitude.*
ID labelling and film production in the developing machine. The films cannot be processed further	- *Checks the images on a preview screen in the examination room* - *Decides whether additional images are required* - *Sends images from the preview screen to the quality control screen (QC)*
EVALUATING PHASE	
Reviews previous X-ray films	*Increased access to previous images*
The films are mounted on the light board outside the examination room. A radiologist checks quality of the films before completing the examination and sending the patient home	*Digital images are retrieved and presented on the QC screen, with quality assurance by radiographer directly*
No such requirement	- *Selects images* - *Discards images* - *Monitors images* - *Processes digital images* - *Decides whether examinations are complete. In the case of uncertainty, a colleague or radiologist may be consulted.*
No such requirement	*Sends patients home*

Table IV: The changes in radiographers´ knowledge demands in the transition from an analogue to a digital environment

ANALOGUE ENVIRONMENT	DIGITAL ENVIRONMENT
PLANNING PHASE	
Embrained knowledge	
Structured check of request and planned examination	*No change*
Prioritization	*No change*
Encoded knowledge	
Use paper documents and protocols to prepare for the film production work	*Use digital documents and protocols to prepare for the image production work*
Embodied knowledge	
Not applicable in this phase	*No change*
PERFORMING PHASE	
Embrained knowledge	
No such requirement	*"Decisions making"- whether enough images have been produced*
Knowledge of X-ray physics to minimize X-ray dose given to patient	*No change*
Encoded knowledge	
The radiographer chooses the organ and automatic exposure parameters are applied; to a limited , extent the radiographer sets the exposure parameters	*The radiographer chooses the organ, but the system sets kV milliampere seconds. If exposure parameters are not optimal post processing is used. The exposure parameters can, if needed, be manually changed*
Embodied knowledge	
Positioning patient	*No change*
EVALUATING PHASE	
Embrained knowledge	
Check films/anatomy/image criteria	*No change*
No such requirement. Sometimes applicable on own initiative	*Analyse images /pathology/image projections*
No possibilities for processing films. If examination is unsatisfactory it must be repeated	*Understand effects in images after processing them*
No such requirement	*"Decision making" whether it is possible to send the patient home or to the hospital ward*
Encoded knowledge	
No such requirement	*Process images*
Embodied knowledge	
Hang films on light board	*No such requirement*

6.1 RADIOGRAPHERS´ WORK PRACTICE AND KNOWLEDGE DEMANDS IN THE ANALOGUE ENVIRONMENT

6.1.1 Planning examinations

The work process in the radiology department begins for the radiographer when a request from another unit/doctor reaches the laboratory. If the patient has existing old reports, the radiographers read them to facilitate the planning of the new examination. The paper request contains the patient's identity, the name of the referring physician, appointments and clinical diagnosis, questions and the patient's history.

"The request is a very important tool for me, which helps me at a starting point in the planning work".

The radiographer reads the request and factors that need to be considered, e.g. if the patient is bedridden; whether the patient is getting the treatment in the hospital or through the primary care services.

Radiographers apply conceptual skills when they check the paper request. Thinking knowledge is characterized by, for example, various prioritizations in preparation activities for different types of examinations. This may include deciding on the sequence in which the examinations should be performed, and setting priorities for imaging production. The radiographers do different kinds of prioritization in different ways, some of them do it **static,** while others do it in a more **flexible** way.

The demands for knowledge in the radiographer's planning work also include the questioning, retrieval and storage of information, e.g. when retrieving documented patient information from RIS, reading guidelines, manuals. This information is used to prepare for the film production work.

"If I'm uncertain about which projections, methods or contrast media to use I consult the method book".

The RIS forces the radiographer to question, read and store the patient information in a specific **structured way**.

Before the patient is shown to the laboratory, the radiographer **prepares** everything for the examination. Then the patient is shown to the laboratory by the nurse assistant or the radiographer and the patient's name and ID are double-checked.

All radiographers knew how to fill out and read the documents and manuals (guidelines) at the department to conduct their work. However, this could be done in different ways, where some more or less checked off items on a list **unreflective** while

others performed the task more **critically reflective,** e.g. working their minds harder with deeper thoughtfulness.

6.1.2 Performing examinations

The patient is **positioned for examination**. If the patients are immobile, either because they are unconscious or due to physical weakness, this process becomes more complex. The film cassettes have been loaded and are fetched. Once the patient is positioned, the X-ray tube is focused, the focus size is set, and if necessary the tube is angled for optimal projection. Following the exposure of the film cassette, the cassette is taken to the film ID label machine and processed. After this, no changes can be made to the resolution of the film, as the film cannot be processed further. Thus, it is very important that the exposure data is properly set.

"…if anything goes wrong a new examination needed to be conducted".

The examination cannot be finalized until the radiologist has checked the quality of the X-ray films:

''I had to wait to quality assure the X-ray film''.

Finally, the radiographer documents the process in the RIS, recording who performed the examination, any drugs administered and changes or amendments to the examination codes. Radiographers apply action-oriented knowledge in the performance of an examination. It is knowledge "in their hands". In this phase, it covers radiographers´ knowledge involved in positioning the patient for optimal projections in various examinations. It also includes the radiographers´ interaction with the patient.

Some radiographers performed the examination more directly from the textbooks, while some radiographers used their artistic competence and feelings at different levels as well as interacting with patients in a more thorough manner when producing images. The observations showed that the radiographers used their interpreted knowledge in combination with their experience from knowing by doing in an individual procedure sequence.

When different types of radiographers worked together it was not always easy, as the two might not have the same preferences about the sequence in which tasks were to be performed. Suggestion: One radiographer might use his or her improvisational knowledge when unable to do an examination, while the other strictly "followed the book". Here, some radiographers demonstrated their flexibility in work and their ability as problem-solvers.

"Sometimes you just have to improvise; you can't always do things by the book".

In the analogue work, the radiographers set code parameters such as kV and milliamperes, applying knowledge of the meaning of symbols, signs and push-buttons. One of the interviewees says:

‘‘These settings are most important as the film cannot be processed from this point”.

The goal of choosing different code parameters is to achieve optimal film exposure, but also to minimize the patient’s X-rays dose, for example by reducing the exposure time (milliampere seconds) and by manipulating the voltage. The radiographers need to use considerable reflective knowledge of radiation protection policies and safety inspection procedures as well as use and maintenance of radiological equipment to optimize patient safety. This is based on traditional **physics knowledge**.

6.1.3 Evaluation of examinations

The evaluating work in the analogue environment is done by the radiologist. However, when X-ray films are produced the radiographer performs an informal **check** of the films. The first stage of this work is to check previous X-ray films for the patient when planning the examination. The second stage is after the examination, comparing new and old films and judging whether the quality of the film is adequate for the radiologist. The third stage is judging whether the old films, or some of them, will be useful to the radiologist. This is done before radiologists assure their diagnostic quality.

“…I need to check the examination when the examination is finished”.

Often in the evaluating work the radiographers reflect on the examinations together with the radiologist. After image quality is assured by a radiologist, the patient is sent home. Paper documents, i.e. requests, are used to write messages to the staff – for instance, that supplementary images should be taken. In this phase there is close communication between radiologists and radiographers, one interviewee expressed

“Instructions, if needed, were given by the radiologists to the radiographers by the light boards…working analogue, the light boards are the meeting place”.

The films are taken down and transported to the reading room, where they are mounted by the radiographer or assistant nurse and read by a radiologist applying embodied knowledge. A findings report is dictated; the films are taken down and transported to the file room, while the tape with the dictated report is sent to a secretary who types the report. Another radiologist may check the films and sign the report. Copies of the report are thereafter sorted and sent to the requesting unit. There is constant and close communication between radiologists and radiographers in all these activities.

“The advantages of the analogue world were that there was more cooperation between radiographers and radiologists”.

The physical spaces are organized to facilitate this close cooperation. There is always a radiologist responsible for each examination. The radiologists work in spaces close to the radiographers. There is an ongoing, and sometimes intense, discussion between the radiologist and radiographer over the examinations before they are finalized. There is generally a close integration in activity between radiologists and radiographers in the context of analogue work.

6.2 CHANGES MADE IN WORK PRACTICE AND KNOWLEDGE DEMANDS IN THE TRANSFORMATION FROM ANALOGUE TO DIGITAL ENVIRONMENT

6.2.1 Planning examinations

The image production work is prepared using **digital technology.** One patient may have several examinations scheduled. It is increasingly important to check that the correct patient and examination have been selected in the PACS system. If not, the images may be transferred to the incorrect PACS folder and thus be hard to find within the system.

The intervention with the RIS and PACS differs from paper documents. In the digital world the radiographer selects appropriate menus in the computer, for example for an ankle skeleton injury, and gets access to menu names for all four projections in the digital environment. There is a need for an increased high level of conceptual skills to plan the examination working with PACS. The system is less flexible and **standardized** and more controlled and requires the individual to know "the way" to perform work in a given order that is the system is enforcing users to do activities in a specific way and order.

"The systems are designed as predetermined models and therefore it is impossible to do things in another way".

Greater knowledge about symbols and retrieving, transmitting and storing information in databases is also needed. For some radiographers, the manuals become a lifeline. One respondent stated that:

"Everything I need to know is in there…it shows how I prepare the control unit and sometimes use the organ keys for selection".

Many times, when reading the manual to check how an examination should be conducted, radiographers instead end up improving the manual, selectively sifting through the content. They have a dialogue with the vendors of the systems to encourage them to improve the system over time. They know "how to use and even develop" documents and manuals. Then they use their critical reflective eyes and they become even more deeply immersed in the documents by getting personally involved.

6.2.2 Performing examinations

As in the analogue work process, the radiographer sets the various parameters on the control panel of the performing modality, including kilovolt, milliampere, the patient's size, and a chamber where the exposure area is selected, as well as the image size. One respondent radiographer describes the process as follows:

"I choose the correct menu, for example for a wrist with or without metal, as these are processed in different ways''.

As the digital image allows post-exposure manipulation, i.e., it is dynamic, the correct settings for image exposure may demand **less accuracy** than film exposure. In practice, this means that the image plates are not as sensitive as films are to X-ray radiation. Less accuracy is required in setting parameters. One interviewee explains it as follows:

"The correct settings for image exposure may demand less accuracy than for film exposure".

Instead of X-ray films being fetched from the file room, previous images for the patient are retrieved from PACS. Working digitally has also introduced new activities demanding computerized interrogated knowledge, e.g. sending images from the preview screen to the quality control screen digitally. However, it is still very important for the radiographers to consider protection from X-rays through their thinking knowledge of physics to achieve optimal examinations and also to minimize the patient's X-ray dose.

In the analogue environment films were hidden in cassettes, so that there was no possibility to decide whether enough images had been produced in this phase. A change when translating into the digital environment was that images were visible "on the fly" as they were produced. The evaluation whether enough images were needed was therefore pushed to an earlier phase in the radiographers´ workflow activity.

Performing the X-ray examination in the digital environment involves two techniques. One is direct digital, using digital detectors, where digital images are produced directly. The second consists of image plates exposed with X-rays using lightweight cassettes. The cassettes need to be processed before they can be made available as digital images from PACS. In the digital world new knowledge of the modality and PACS system symbols and signs are needed. The users must know how to retrieve, transmit and store digital data in various databases and systems. They must know how to interact with a computer actor.

The digital image produced can be presented on a **preview screen** to check that everything needed is included before taking the next image. The preview screen imaging is only intended for a general overview with limited image quality to help

radiographers decide whether they need to produce additional images. Examination of the patient is always conducted as quickly as possible. One radiographer stated:

"I look at the preview screen to perform the examination quickly".

With image plate technology, the image cassette is transferred to the associated reading unit in the modality system. When the radiographers have completed the examination, they **send** all the **images** from the reading unit to the Quality Control function, where the images are checked and thereafter aligned with the RIS data. When images are checked, radiographers use their conceptual skills and cognitive abilities.

In this phase the radiographer needs to make an active decision on the quality of images as well as on whether more images are needed. One interviewee formulated this as follows:

"I check the quality of every image between exposures".

Different radiographers performed examinations in different ways, according to the respondents. Some radiographers were more active, being able to identify and **solve problems** by improvisation in work. For example, if a patient is bedridden and performing the examination requires the patient to be in a sitting position, some radiographers know that if they angle the X-ray tube, the examination can still be performed with the patient horizontal. Others could identify problems but not solve them, they work in an **automatic** way**;** for example, in the situation described above, they did not know how to perform the examination with the patient in a horizontal position. One interviewee described it as follows:

"We need material that is so good that it can be assessed. This isn't always possible, but we have done our very best".

Documenting the image production process, recording who performed the examination, any drugs administered and changes or amendments to the examination codes is conducted in RIS the same way as in the analogue film environment evaluation of digital images. In the evaluation phase, the radiographer reviews the quality of the images and manipulates and refines images to optimize image quality at the image viewing station.

"At the PACS image viewing station I quality assure my images… I can put a black mask around the image, add missing/complete information, and rotate images".

The new responsibilities to quality assure images for diagnostic work requires radiographers to have a greater high-level knowledge of image **analysis.** The respondents describe it in the following way:

"*For example, I want to look at the frontal view of the spine to know which side the patient should lie on when I move on and take the lateral projection or if any angle is required in terms of the X-ray to get an angle between the vertebrae".*

In this phase radiographers tend to just "**check" images** and send patients back to the wards or their homes.

"I check that I have captured the organ in the image".

Others apply deeper cognitive knowledge when **analysing the images**. This calls for a greater knowledge about image criteria, anatomy and physics. Having this knowledge makes radiographers feel more empowered in their role.

Radiographers usually need to **process digital images**. This is done through computed interrogation; one interviewee explained it as follows:

''In the digital world I have the opportunity to correct the image, i.e. if more light or contrast in the image is required I use the process parameters and can instantly view the result".

Radiographers stressed that it is important that they do **not change the image** in a way that alters the information in the image, as this could create the image of a positive pathology in a case that in fact is negative.

Plain radiography examinations, the majority of examinations produced, are usually quality assured by the radiographers. CT, MRI, urinary tract, gastrointestinal and ultrasound examinations are usually quality assured by a radiologist. Access to the images has increased, and thereby the possibility of comparing the new images with those from previous examinations. PACS also enable the radiographers to **select** or **discard** images. When the examination is quality assured, images cannot be discarded by anyone, including the radiologist. When the radiographer is satisfied with the images, they mark the examination as complete and the images are made available on the image network for distribution, interpretation and reporting. The physical distribution of work, where the radiologist and radiographer do not necessarily occupy the same space, and where they no longer gather around a light box, as well as the reorganization of work assignments, hampers communication and close cooperation between radiologists and radiographers.

At the sites visited, the X-ray examination rooms were situated at a distance from the workstations where the images were interpreted; this in itself had an effect on work practice. One of the radiographers described the impact in the following way:

"Spaces are used in new ways and we have not found any new meeting place".

6.2.3 Sending patients home

One result of transferring quality assurance of images from radiologists to radiographers is that the radiographers are now often the professionals who **send the patient home** after the examination. One of the radiographers described this in the following way:

"In the digital world I quality assure the images in more detail - this requires more time in the image production before I send the patient home; I send a lot of patients home".

In situations where the radiologist is of the opinion that the examination should be supplemented with new images, this often cannot be done immediately, as the patient has already been sent home. So the entire examination process must be repeated from the start. This contrasts to the analogue world, where the organization requires the radiologist to check all examinations before the patient is sent home. PACS had the functionalities that enabled the reorganization of work. The technology itself does not directly cause these organizational changes, but it does make it possible for them to take place. The changes are triggered by many intertwined factors - behavioural, organizational, and technical.

7 DISCUSSION

Table V summarizes the properties of the various components of knowledge in the image production process. It also illustrates that there are two different levels of knowledge, represented by the routine actor and the reflective actor. A radiographer has a mix of all these properties of knowledge in work. This study shows that within the different components of knowledge, i.e. embrained, encoded and embodied knowledge, one category is more central to one individual than to another.

Table V: Summary of different levels, components and properties of radiographers´ knowledge.

Routine Actor	***Reflective Actor***
Embrained Knowledge	
Static	Flexible
Check images	Analyse images
Encoded Knowledge	
Unreflective	Critical and reflective
Embodied Knowledge	
Automatic action	Problem-solving action

There is a circumstance that should be considered when assessing the credibility of the study. The study includes a limited numbers of interviews (N=22). The study illustrates that actors with a reflective profile are better suited for radiographic work. These actors have a profound embrained, encoded and embodied knowledge, with the result that they know how to perform work in an optimal way. Their inherent knowledge enables them to know how to act in various situations. This reflective profile becomes even more important in the transformed digital environment, as work is more independent with increased responsibilities. A summary of the properties of the reflective profile appears below.

Reflective actors:

- Work flexibly as well as take on many initiatives at work
- Find pleasure and are satisfied with the result when they analyse the quality of images
- Develop different kinds of procedures, instructions, guidelines, etc.
- Without close supervision or monitoring, assume the responsibility assigned to them as they perform the work
- Strive every day to achieve excellent results in their work as problem solvers
- Do not expect and do not need appreciation of their work from others, colleagues or managers; they are independent individuals

7.1 WORK CHANGES AND KNOWLEDGE DEMANDS IN THE PLANNING WORK

The study illustrates how the radiographer plans and sets priorities in the image production process, and it also suggests that the planning work is very similar in the analogue and the digital environment. The difference is, as Lundberg (2000) described it, that the radiographers in the digital image production process prepare their work using modern technology. In these situations the radiographers undertake various prioritizations in preparation activities for different types of examinations, e.g. which patient they are going to examine, in what order the examinations should be performed, and priorities for imaging production. The radiographers are then using their *embrained knowledge*, as Blackler (1995) describes knowledge that depends on peoples' conceptual skills and cognitive abilities. Some radiographers worked as **routine actors** in a **static manner** and followed the appointment schedule. It has been illustrated that even routine actor radiographers with few years of experience may reveal a critical reflective mind that is active in their work. Radiographers´ work is becoming more isolated; this makes it clearer whether they are working in a more routine or more reflective way when approaching their work. Today there is a clearer need for the use of good judgment, e.g. making carefully considered individual decisions in work; this also calls for **flexibility** in work. *Embrained knowledge* could also be related to flexibility. Flexibility involves radiographers' ability to adapt their thinking and planning to different situations. The flexibility aspect of the embrained knowledge requires the radiographer to be adaptable with regard to altered circumstances. In these circumstances the radiographer needs to be flexible, not mechanically following the department's rules or the roles all the time. Maltén (1997) states that to achieve a reflective, insightful knowledge you need to have basic theoretical knowledge.

Other radiographers work as **reflective actors** and set priorities based on the sequence of examinations and even on information from patients. The routine actor is usually, but not necessarily, a more "junior" radiographer and the reflective actor is usually a

more “senior” radiographer. Ellström, Gustavsson & Larsson (1996) describe different levels of actions, characteristics and knowledge base. For instance, they describe the level of skill-based action related to automatic processing and routinization that is typically built on tacit knowledge. Further on they also highlight the level of reflective action related to critical reflection on tasks, goals and other conditions built on meta-cognitive knowledge (ibid).

The knowledge demands for the radiographer's planning work also include *encoded knowledge*. Blackler (1995) describes this as conveyed by signs and symbols represented textually and digitally de-contextualized. Radiographers in the analogue environment use encoded knowledge when they work with paper requests, guidelines, manuals, etc. in paper files. In the digital environment, radiographers draw on encoded knowledge when they open appropriate menus in the computer for an ankle skeleton injury, for instance, and obtain access to menu names for all four projections in the digital environment. Using different kinds of documentation systems helps the radiographers to do their day-to-day work. For routine actors, it means that radiographers simply know how “to use” the documents and manuals (guidelines) at the department to conduct their work in an **unreflective** way. It is the unreflective routine actors who follow the manuals, protocols and other documents from A to Z in order to perform an examination.

Radiographers who work as reflective actors may consult a manual before performing rare examinations. Often, when reading the manual to check how an examination should be conducted, they instead end up improving the manual, selectively sifting through the content. They know “how to use and even develop” documents and manuals. Then they use their ***critical and reflective*** eyes and they become even more deeply immersed in the documents by getting personally involved.

Owen, Hogg & Nightingale (2004) believe that the protocol should include an explanation of how to proceed when radiographers reach the limit of their ability. It should refer to the initial training required to undertake clinical duties as well as the ongoing continual professional updating required to maintain competence. Audit of practice should be indicated, including the preferred audit methodology, and associated with this should be a clear statement about standards and what to do if standards are not adequately met. Protocols should be archived, in a paper-based form, for lengthy periods in case of legal claims. On the archived protocol the date it was in clinical use should be included.

7.2 WORK CHANGES AND KNOWLEDGE DEMANDS IN THE PERFORMING WORK

The technology has produced changes in the distribution of responsibilities in work and changes in the organization (Costaridou, Panayiotakis, Sakellaropoulos, Cavouras & Dimopoulos, 1998; Lundberg, 2000). Issues such as decisions on whether to add images to the examination can be addressed much faster in the digital milieu, depending on the technology. Digital work has thus led to an empowerment of radiographers, as they have greater responsibilities and make far more decisions.

In their performing work, radiographers are required to use their *embodied knowledge,* which is described by Blackler (1995) as action-oriented and context-specific. This type of knowledge is "in their hands", and for radiographers it often involves image-taking techniques. Embodied knowledge is originally built upon information and commonly described and presented in textbooks. Thereafter, it is interpreted by the radiographer individually. Finally, through experience, it becomes embodied knowledge. In this phase, the knowledge demands for radiographers involve being able to position the patient in different ways to develop images in different projections. Some radiographers work as routine actors and do the examination in an automatic way, directly from their textbook knowledge. Other radiographers use their artistic competence and feelings at different levels when they produce images. The radiographers used their interpreted knowledge in combination with experience from knowing by doing in an individual procedure sequence.

Nonaka (1994) describes practice knowledge as "knowing how": action-orientated knowledge of experience or hands-on experience (doing), or practical thinking, while Hiebert, Gallimore & Stigler (2002) describe the difference between practitioner and professional knowledge. Practitioner knowledge is linked with practice — it is detailed, concrete and specific, as well as integrated and organized around problems of practice. Professional knowledge, on the other hand, is described as public. For knowledge to be public it must be represented in such a way that it can be communicated among colleagues. Professional knowledge should also be storable and shareable through theories. Professional knowledge also requires a mechanism for verification and improvement through repeated observations (ibid).

Schön (1987) introduced the concept of reflective practice. He stated that reflective practice involves thoughtfully considering one's own experiences in applying knowledge to practice while being coached by professionals in the discipline (ibid). It is not always easy to be a routine actor, such as when these individuals followed the more reflective actor radiographer's approach - things were not done in the same sequence although the result was of similar high quality. The reflective actors used their improvisational knowledge when unable to do the examination as they used to do it or by the book. Here, the radiographers demonstrated their flexibility in work and they needed **problem-solving** skills. They solved problems in different ways when they

were doing an examination. In the digital environment, the demands of knowledge for performing work are that the radiographers use their embodied knowledge. They use it in a similar way as in the analogue environment, when they are going to perform examinations. How well the radiographer performs this activity differs: some are routine actors who work **automatically** and do things by the book, following the rules, while other radiographers solve problems through improvising. This is another view of *embodied knowledge* as knowledge about how to do something. Scribner (1986) describes practical thinking as problem-solving techniques which depend on an intimate knowledge of the situation. To use embodied knowledge in a problem-solving way was important in the analogue environment, and it is also important to have this perspective in the digital environment, because the radiographers work in a more isolated way. Hiebert, Gallimore and Stigler (2002) highlight another characteristic of knowledge that is linked with practice; it is integrated and organized around problems of practice (ibid). Evidence-based practices have become increasingly important in health care because they provide a framework for clinical problem solving that allows practitioners to stay up to date with current best practices in their field.

In the performing work in the analogue environment, when radiographers set parameters, they are required to use *encoded knowledge.* The radiographers use the encoded knowledge as routine or as reflective actors. In the digital performing work, the demands of knowledge are that the radiographers use the encoded knowledge as in the analogue environment, when setting various parameters. This is associated with wider latitude for the digital plates. The radiographers also send images from the preview screen to the quality control screen digitally.

In the digital performing work, the knowledge demands also include *embrained knowledge,* when the radiographers view the preview image screen and decide whether they should add any images. In this phase the radiographers do not analyse the images; they simply check them.

7.3 WORK CHANGES AND KNOWLEDGE DEMANDS IN THE EVALUATING WORK

The study also illustrates the pronounced differences in the evaluating work in the digital environment. The physical distribution of work, in combination with new task assignments, has hampered communication and close cooperation between radiologists and radiographers. In the analogue environment, the radiologist quality assured the films. According to Bolman (in Bramson & Bramson, 2005), changes disrupt the way things are done and trigger two competing responses. The first is to keep things as they are — to keep replaying the past. The second competing response is to ignore the past and rush headlong into the future. Individuals and organizations can get stuck in either response or bounce back and forth between the two (ibid). In the digital world, however, the radiographer often assesses the image quality at the image viewing workstation. One result of the shift of image quality assurance from radiologists to

radiographers is that radiographers are now frequently the professionals who send patients home after performing the examination. In this change, radiology has separated the production of images from the interpretation of images. According to Donovan & Manning (2006), analyzing and reporting on images is currently an extra role for radiographers. Radiographers can provide a descriptive report but lack the training and flexibility to provide a medical report and make judgments about the relevance of radiological findings (ibid.). No area of this role extension is more hotly debated than that of radiographers´ reporting procedures. The Royal College of Radiologists and the Society College of Radiographers in UK, released a statement on the delegation of radiological reporting in which distinguish between a technical report and a diagnostic report (ibid). Although Donovan & Manning (2006) are critical of assigning the reporting on images to radiographers, they also concur with the above. In Britain, for instance, courses are offered in radiography departments, to train radiographers in the first-line reporting of plain radiography (Cunningham, 1997). Alderson & Hogg (2003) emphasize that radiographers need to know when they have reached the limit of their abilities and consequently when to ask for advice from a medical practitioner/-radiologist.

The evaluating work in the analogue environment does not focus on the radiographer's work practice, but on the radiologist's work practice. The X-ray film is displayed on a light board, and if it is the radiographers who hang the X-ray films, then they are using their *embodied knowledge.*

In some situations the radiographers view the X-ray films and make decisions in the analogue environment, and then the radiographers are using their *embrained knowledge*. Some radiographers work as routine actors and just **check** the films. Usually in the analogue environment the radiographers evaluate and reflect over the examinations together with the radiologist. Radiographers work as reflective actors in the analogue environment too, evaluating work and reviewing the images to decide whether the image criteria for the relevant examination have been fulfilled. They can do so when they know more about the image criteria, anatomy and physics, which helps them to feel more secure in their role. In this specific situation, deeper and more thorough *embrained knowledge* is required in the context of reading images.

In the translation from analogue to digital, there is a loss in the communication between the radiologist and radiographer. This loss requires adjusting assumptions, beliefs, or work patterns that worked well in the past to embrace a new way of doing things (Bramson & Bramson, 2005). Loss is an unavoidable by-product of change, even when the change is a positive one that people know will make work more efficient and improve customer service. People take pride in their past accomplishments in the organization. When change is proposed, it is often perceived as a rejection of how they always have done things. The perception that core values are changes is common when people talk about losing something in the change process. These feelings of loss frequently foster resistance to the changes (ibid). Markus (2004) show that involving the people who are going to use new technology in decisions about how to implement

the system not only produces better results but also helps overcome resistance to the changes in how work gets done (ibid).

The evaluating work in the digital environment focuses on the radiographers´ work practice, such as quality assurance of images. When reading the images, they need to decide whether the image criteria for the relevant examination have been fulfilled. How well the radiographer performs this activity differs between the routine actor and the more reflective actor. The demands on the radiographer's knowledge then involve embrained knowledge. The radiographers who work as routine actors just check the images, while the reflective radiographers use embrained knowledge through **analysis of images**. They can do so when they know more about image criteria, anatomy and physics, which helps them to feel more secure in their role. In the context of reading images, it means deeper and more thorough embrained knowledge in this specific situation. Atkins and Murphy (1993) describe how, in reflective nursing practice, nurses engage in critical analysis of the situation in which they find themselves, thus discovering new ways to intervene through questioning their knowledge and usual responses (ibid).

In the evaluating work, radiographers use the *encoded knowledge* in the digital environment when they are processing the images. In this situation, too, they work as routine or as reflective actors. At this stage it is important that the radiographers have the knowledge not to change the image in a way that alters the information in the image, as this could create the image of a positive pathology in a case that is in fact negative.

In the digital environment, however, all images are accessible for radiographers to process: the radiographer does not release any plain radiography images without first reviewing them. This means they review their images more frequently today. The great difference between X-ray films and digital images is that X-ray films cannot be processed further, while the digital images can be altered and manipulated in various ways.

8 CONCLUSION

This study emphasized the tools and their properties, as well as knowledge demands in the image production work process. The purpose was to show how the radiographers' work practice and knowledge demands change in the transformation from analogue to distributed work. The study concludes that since the introduction of PACS the radiographers work practice changed, they need to perform new activities, have new responsibilities and communicate in new ways. It also concludes that the role of the radiographer has changed in three principal areas: 1) communication in work, 2) image processing and 3) image quality assurance, in addition to sending home patients. The study also explores that the radiographers' knowledge demands changed in the image production process. The study illustrates that radiographers need to be more **flexible** in their work; there is little room for **static** work. In their work they need to **analyze images** — it is not enough to "**check them off**"; it is not possible to just read documents — they need to interpret them to ensure optimum performance. Overall, radiographers need to have a **critical and reflective** mind in practice — it is not enough to work in an uncritical way. Since the work is full of **problem-solving action** it is not enough to perform it adopting an **automatic** approach. Radiographers use embrained, encoded and embodied knowledge, aspects that seem to be important for understanding the effect of knowledge in practice. Radiographers use their knowledge in different levels as routine actors or reflective actors. Becoming a reflective radiographer, practicing detailed memorization, is not always related to years of work experience.

FUTURE WORK

Future research on radiographers' work should focus on designs and implementation of an innovative groupware system for radiographers that supports communication and learning in work. Other studies are planned to observe if new requirements in terms of competence will lead to new ways of organizing work within the field of radiography. If so, how? Another natural follow-up would be to explore ways of cultivating independent thinking skills and to investigate how to nurture these individuals. Can various teaching methods, such as problem-based learning, case methodology or reflection groups help to prepare flexible, critical, reflective, and problem-solving actors?

9 TILLKÄNNAGIVANDE

Forskning i sig är en resa och på min resa som varit lång och med en del sidospår, så har det funnits många medresenärer, förutan vilka detta arbete inte hade kunnat genomföras!

Därför vill jag tacka

Min huvudhandledare, inspiratören, den alltid lika engagerade, Nina Lundberg som ställt krav och när jag sviktat, uppmuntrat mig att köra på. I hennes mail och sms har stått *”Full fart fram!”*

Peter Aspelin, min bihandledare, giganten inom radiologin. Denna, för forskningen brinnande, varma person, som har varit ifrågasättaren, alltid tillgänglig oavsett var i världen han befunnit sig.

Bo Jacobsson och Magnus Bergquist för sina konstruktiva och värdefulla kommentarer.

Margreth Forbes och Cathrine Brix som flitigt har läst och redigerat min engelska, jag kan inte nog tacka Er!

Helena Forssell, denna underbara människa som kan ”ALLT” ”ALLTID”

Forskningsgruppen: Kent Fridell, Kerstin Hillergård, Lars Lindsköld, Marianne Selim och Joachim Wallberg, denna diskussionslystna och kreativa grupp, hur kul som helst att träffa.

Kollegor i sjuksköterskeprogrammet vid KI, enheten VIKO och då alldeles särskilt min chef Elisabet Welin Henriksson och Lena Oxelmark, Johanna Ulfvarson, Christina Rehn Ulaner, Agneta Landin, Ingela Lennström, Åsa Hägg, Marie Iwarzon och Elisabeth Strandberg, dessutom Elisabeth Winnberg och Stina Johansson, som stöttat på olika sätt.

Tidigare kollegor och då speciellt Ulla Finati, Görel Bergmark, Kent Lundqvist, Kristina Dahlin och Barbro Mendel - som gör mig så GLAD!

Goda vänner som känt till mitt arbete, men kanske förundrats över den tid det tagit.

Mina systrar Annica och Yvonne som egentligen inte vet vad jag håller på med, men som är så viktiga för mig. Min älskade systerdotter Chatrine som precis skriver sin kandidatuppsats, hon ger mig styrka.

Min far Filip som följt detta arbete med stort intresse och som är så stolt över mig.

Barnen, Filip, Lucas, Jennifer och Alexander, det är Ni som ger mig energi, vilket skänkt mig kraft till allt nattarbete som behövts.

Sist men inte minst, min Älskade Man och färdkamrat, som hejat på och uppmuntrat mig på denna resa!

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