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Karolinska Institutet, Stockholm, Sweden

LEARNING BY DOING – RADIOGRAPHERS´ KNOWLEDGE AND LEARNING STRATEGIES IN THE DIGITIZED HEALTHCARE ENVIRONMENT

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Stockholm 2014

“To my beloved husband
Curre
the man in my life
I just love you”

ABSTRACT

The aim of this thesis was to inform the field of radiography of changes related to the digital image production process, by understanding how radiographers perform tasks and apply knowledge as well as learning strategies in work practice.

The method of this study adopts a qualitative ethnographic approach, using participant observation of and semi-structured interviews with radiographers at six Swedish hospitals. In total, 37 radiographers were interviewed, 25 of whom were observed. The interviewees were divided into two categories, novice radiographers working one year or less, and experienced radiographers working five years or more. The thesis classified the radiographers' work as the: 1) Planning phase, 2) Performance phase, and 3) Evaluation phase. Blackler's theory of knowledge components was applied to identify properties of knowledge.

The results illustrated that the introduction of PACS did not simply entail the transfer of data and information from the analogue to the digital world, but also new activities, new ways of communicating, new responsibilities, new decision–making routines, new image processing and new technological knowledge for the radiographers. The thesis also illustrated that the radiographers applied their knowledge in different ways. Some radiographers applied their knowledge in a more reflective way, while some more routinely. They used embrained knowledge when planning X-ray examinations in a static or flexible way, and when viewing film/images they checked or analyzed them. Encoded knowledge was required for using various kinds of documentation in a reflective or a critical reflective way. Embodied knowledge was called for when action had to be taken in an automatic or problem-solving way. Further on, results showed the differences between novice and experienced radiographers' learning strategies. Novice radiographers applied the following learning strategies together with critical thinking in the planning and evaluation phase: Memorization combined with logical reasoning and inquisitiveness, open-minded and focused observations, selective reading, and information-seeking. They communicated through active and attentive listening, asking questions, receiving information and feedback, discussing problems, and speaking aloud to themselves. In the performance phase they applied doing combined with flexibility, repetition combined with perseverance, and finally, imitation. Experienced radiographers applied the following learning strategies together with critical thinking in the planning and evaluation phase: Memorization combined with logical reasoning, prediction and contextual perspective, reflective discrimination on focused observations, selective and validated reading, and information-seeking. They communicated through listening in an analytical and critical way, answering questions and providing feedback, and discussing problems. In the performance phase they applied: Visualization combined with intellectual integrity, doing combined with creativity, repetition combined with perseverance and finally, experimentation combined with confidence and intuition.

The conclusion of the research showed that the role of the radiographer and knowledge requirements have changed in four principal areas: 1) Communication in work, 2) Image

processing, 3) Image quality assurance, including sending patients home, and 4) Decision making. The radiographers used embrained, encoded and embodied knowledge, and they applied knowledge in different levels as routine actors or reflective actors. The difference between routine, novice radiographers and reflective, experienced radiographers respectively was the way in which they applied their knowledge and learning strategies combined with critical thinking. It was important to identify the differences in how radiographers applied knowledge and learning strategies, because this may yield possibilities for fostering the transition from novice to experienced radiographers. The more reflective profile has become even more important in the digital environment as work is more independent and offers greater responsibilities. Consequently, radiographers' tasks have become more demanding and highly scientific.

LIST OF SCIENTIFIC PAPERS

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, 2009;15 (3):e11-21

III. Learning Strategies in the Planning and Evaluation Phase in Image Production.
Larsson W. Aspelin P. Lundberg N.
Radiography, 2013; 19 (4): 347-352

IV. Learning Strategies in the Performance Phase of Image Production.
Larsson W. Aspelin. P. Fridell K. Hillergård K. Lundberg N.
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1 INTRODUCTION

"The things we have to learn before we can do them, we learn by doing them"
Aristotle

The above quotation shows how important it is with learning in work practice. There is not any learning whatsoever, it is the meaningful learning that is essential in today's fast information- and technological society in which there is constant progress and change. 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.

This thesis use three work phases that exist in the image production process, both in the analogue and in the digital environment. These phases are the: planning, performance and evaluation phase. The phases are defined as follow: 1) the planning phase of the image production process is the preparation before the patient enters the laboratory. This phase includes activities such as authentication of the radiographer to access the computer system, contacting clinical wards to clarify issues confirmation of patients' physical mobility, and patients' psychological status, reading the manual to find information how to perform the examination, using the control panel to select the correct examination and prepare various parameters, preparing and handling contrast media and other drugs, as well as contacting the appropriate department for patient transportation after the examination has been completed. 2) The performance phase of image production process begins when the patient enters the laboratory until the patient leaves the radiology department. This phase includes the following activities: a) preparation of the examination apparatus including the examination table and the protective paper placed on the table; b) complementing with other items needed in the laboratory room, e.g., a pillow, brute bag, toys; c) retrieving the patient; d) informing the patient before starting the examination; e) positioning the patient; f) if necessary, applying patient radiation shields g) performing the X-ray examination; and h) informing the patient after the examination. 3) The evaluation phase of image production process is defined as the follow-up work conducted after the requested examination has been completed. In this phase, the patient may still be at the radiology department. This phase includes the several activities as, documentation in the radiology information system (RIS) e.g. signature, amount and strength of the contrast media and/or other drugs, information on whether it is difficult for the patient to be still, sorting, processing and hanging images in the PACS system and analyzing and/or checking of the completed images. The latter work activity may include

communication with colleagues and/or radiologists concerning possible retake or completion of images. The image production process includes all three phases, in summary it includes: the structuring and prioritizing before the examination, performing the examination, evaluation of the examination and finally end of the examination.

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). The concept of digitalization relates to the technology (Fridell, 2011 & Lundberg, 2000 in Lindsköld, 2012). Initially, the changes in radiology were made in new modalities such as computerized tomography, ultrasound and, in a later phase, the implementation of magnetic resonance tomography. The digitized healthcare environment was implemented 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. It can simplify and speed up an Information Technology (IT) integrated the workflow throughout the hospitals (Nitrosi et. al 2007). PACS was intertwined with the Radiology Information Systems (RIS) that hold the textual information concerning the patient's visits and history (Lindsköld 2012). Further on Lindsköld (2012) highlights that the technology is a part of a larger information infrastructure. Other typical things for the digitized environment is that it is filmless, workflow optimization, faster availability of the reports, monitoring work, process images, share data etc. (Fridell, 2011; Hillergård, 2013; Lindsköld, 2012; Lundberg, 2000; Nitrosi, 2007).

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. And the new technology requires not only new work routines but also demands of new knowledge and learning strategies for the radiographers (Fridell, 2011).

The technological changes in healthcare also included people and changes in their work practice (Barley, 1986; Linderoth, 2002; Lundberg, 2000). The people in the technology work practices become users. The concept of distribution relates to collaboration in a social context (Lundberg & Fridell in Lindsköld, 2012). In the context of implementing new technology Orlikowski (1996) describes the importance of the staffs "mental model" as a crucial element of how new technology is received. She considers that the staff's focus is based on their experiences and stresses the importance of experience. To define the differences between novice and experienced radiographers, the thesis was inspired by Benner's definition of the concepts. The concept of novice agrees well with Benner's definition of advanced beginner nurses who are characterized by rule-governed behavior that is limited and inflexible, general rules are taught in order to provide help for performing tasks and principles. The concept of

experienced agrees well with Benner's definition of the proficient and an expert nurse, the proficient nurse perceives and understands situations as a whole. The expert nurse defines as is highly analytical skilled and has an intuitive grasp of each situation. The work of an expert nurse is characterized by a deep understanding of the total situation. Further on Ellström (l996) describes the routine actor as having reached the base of "procedural knowledge‘', while they describe the reflective actor as having reached the base of ‘'declarative knowledge". Novice is synonymously referred as routine radiographers and experienced are synonymously referred as reflective radiographers. Van Bolhuis-Poortvliet and Snoek (1996) in Van Woerkom, Nijhof and Nieuwenhuis (2003) highlight that the concept of reflection is a mental activity. Flavells (1979) description of reflection is more detail; it's about consciousness on one's own knowledge, both strengths and weakness. According to Manninen (2014) the reflection results in new knowledge and skills and increased competence and self-confidence.

Van Woerkom et al. (2003) highlights eight dimensions to reach critical reflective in working after they have analyzing a case-study, the dimensions are: "reflection, learning from mistakes, sharing one's vision and views, challenging groupthink, asking for feedback, experimenting, sharing knowledge and being aware of their own level" (ibid pp. 193). Shaeffer and Rubenfeld (2000) describe the concept of critical thinking as follows:1) cognitive skills in practice, and 2) habits of the mind. Both main categories include different components, the cognitive skills in practice includes seven different components: logical reasoning, predicting, discriminating, information seeking, analyzing, transforming knowledge and applying standards, while the habits of the mind include ten components: confidence, contextual perspective, creativity, flexibility, inquisitiveness, intellectual integrity, intuition, open-mindedness, perseverance and reflection.

Several British studies are focusing on the radiographers "new" reporting activity working with PACS (Brealey, et al. 2005; Brealey & Scally 2008; Paterson, Price, Thomas & Nuttal, 2004). However, to the best of my knowledge there are no previous studies that illustrate the impact of digitalization on the knowledge and learning strategies of the radiographer's. Such studies require knowledge of radiographers work activities, learning strategies and how they use their knowledge in these activities. The aim of this research is to inform the field of radiography of changes related to the digital image production process, by understanding how radiographers perform tasks and apply knowledge as well as learning strategies in work practice.

The reasons why the focus has not been on radiographer's knowledge and learning may be that digitalization has been conducted quite recently and that knowledge and learning 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 professions work practice has always been intriguing. This initiated the research work. Hopefully this thesis can contribute to the understanding of the professional role, knowledge and learning strategies of the radiographers.

The remainder of the thesis 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 the concepts knowledge and learning. In Section 4, Blackler's knowledge organization theory is presented as well as criticism of the theory. Section 5, describes the material and method with focus on ethnography in health care and how the ethnographic method is applied as well as criticism of the ethnographic method. The thesis analyzes process and ethical considerations are also presented. Section 6 gives the main results from the papers. Section 7 contains the discussion and finally, there are sections on concluding remarks and future research (section 8 and 9).

2 AIM OF THE STUDY

The main research question was “How do radiographers work practice, knowledge and learning strategies change in the digital image production process?” The aim of this research is to inform the field of radiography of changes related to the digital image production process, by understanding how radiographers perform tasks and apply knowledge as well as learning strategies in work practice.

The main research question and aim have been addressed by considering the following issues:

1. How does the transformation from analogue to digital environment change radiographers work practices?
2. How does the transformation from analogue to digital environment change radiographers’ requirements of knowledge?
3. What kind of knowledge do routine and reflective radiographers use in the digital image production process?
4. Which learning strategies do novice and experienced radiographers apply in the digital image production process?

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

3 BACKGROUND

This section provides a brief description of the radiological service, radiological techniques and systems, knowledge, learning and finally related research.

3.1 RADIOLOGICAL SERVICE

Radiology departments are service units for all kinds of clinical departments within healthcare. 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 centers. They are managed in Sweden by the public health service and county councils or by private providers. According to Frank et al. (2012) there are about 250 radiology departments in Sweden, were more than 5 million radiology examinations is conducted per year. 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, gastro¬¬intestinal, urinary tract, computer tomography (CT), 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 developed to make the diagnostic work modern, safer and easier for the organization, different professions and for the patients (Lundberg, 2000). 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 gynecological 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).

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 and 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).

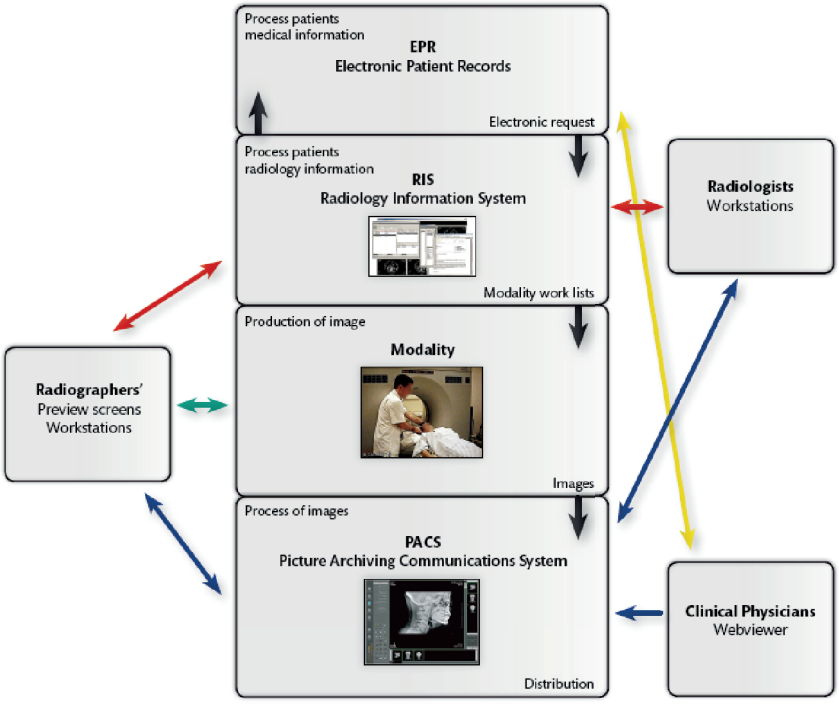

Figure 1. Digital radiological environment.

3.4 KNOWLEDGE

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 & Duguid 1991; Czarniawska 1997; Knorr-Cetina, 1999). Blackler (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.

3.5 LEARNING

Learning happens every day on the job and in real life. It is important to clarify that there is not only one right way to learn. Learning is a wide concept, maybe it is therefore there are, a lot of and variety definition of the concept. One of all definition is that learning is social and a kind of active process, involving information exchange and covers the efforts to absorb, understand and respond on the world (Chetley & Vincent, 2003; Wirth & Perkins 2014). It implies a process of self-directed exploration, a process of personal transitions and discovery, in search of something not yet known. Learning take place in individuals and it increase individuals ability to participate in the society and it is a process that expanding the capabilities of individual and organization (Engeström 2001; Nonaka, Toyama & Konno, 2000; Wenger, 1996). Marton and Booth (1997) mean that one of the key components for learning is structure and variation. Illeris (2004) pointing out that learning is about getting new experiences and through reflections and discussions transform the experiences into new knowledge and skills. The learning activity is about "skills, insights, beliefs, values, attitudes, habits, feelings, wisdom, shared understandings and self-awareness", to reach effective learning it demands questioning, listening, challenging and enquiring (Garavan et al. 2003, in Sheridan & Linehan, 2011, pp 12). Ellström, Löfberg and Svensson (2005) and Illeris (2004) focused on employees learning in work place and conclude that their learning depends on their experience from their life and work, previous knowledge, and it is also influenced by the individuals' attitudes, socialization and education. When Lave (1997) describe learning in practice she focused on the relations between the learner and processes in the setting that may transform the problems for the learner. On the contrary, learning strategies is something beyond learning; Oxford (2003) define it as: "specific actions taken by the learner to make learning easier, faster, more enjoyable, more self-directed, more effective, and more transferable to new situations" (Oxford, 1990, pp. 8). Out of this it can be concluded, that learning is complex and that it is built on social constructions, develops socio-cultural processes and also leads to construction of personal understanding (Lave & Wenger, 1990).

3.6 RELATED RESEARCH

3.6.1 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 successful project "cultural" changes at the individual's level are required.

Studies were also focused on the change in the radiographer's 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 (2011) focuses in his thesis on several professions in health care related to the radiology environment as: radiologists; radiographers and orthopedic surgeons. The thesis describes the different professions changed professional role in the transition from analogue to digital radiology environment. The result shows that the radiologists felt secure when using the analogue technology, while they initially felt insecure when using the digital technology related to the technology. This uncertainty decreased over time. The radiographers saw a great potential with new ways of working and where the new technology was seen as a support in the new working process. The orthopedics has shifted from a static practice in the analogue environment and to a more flexible practice in the digital environment. This shift relates to the technology development and to new routines in practice. 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.

Lindsköld (2012) concluded in his thesis that the transformation of digital data in local systems into virtual information infrastructures consumed within the healthcare enterprise creates greater potential for using the digital information. Access to and handling of information within the healthcare enterprise is simplified and more efficient, this supports the planning and logistics of work.

3.6.2 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, dieticians, 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 and 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.

Hillergårds (2013) thesis illustrates that radiographers' work practice is complex and include different types of knowledge as: embrained knowledge, embodied knowledge and encoded knowledge. These different kinds of knowledge were mixed and were applied in different levels, either routinely or reflectively. Because of the change from analog to digital environment radiographers' requires new knowledge about diagnostic and image quality control and also knowledge about information systems.

3.6.3 Learning required in health care and in radiological work

Mogensen (1994) studied nurse students learning in the practice part of nurses education, because it was important to understand the learning process in nursing education as a complex interplay of different parts. Three forms of mental representation were found to be predominant in the students' construction of knowledge – the narrative, the mental picture

and the sensory motor form. The conclusion in this study was following "The clinical practice – that's where you learn!" Wenger (1998) also focusing on nurses students and describe that they need to have peripheral participation of practice, a community that for student nurses can be on different wards at hospitals, at health centers and in community. The community itself defines as involving relations between persons, activities and the world (ibid).

Lindquist (2006) study explored physiotherapist student's experience of learning throughout the three year education. The result shows three patterns of learning ranging from cognitive to a cultural view of learning, described as 1) performing treatment, 2) solving problems, 3) managing health. The students indicate different ways in learning to be a physiotherapist, the different ways was: the ways that learning occurred, learning together with whom and in what context learning took place.

In a study by Dickson (2004) shows that radiographers need new skills and competences to keep up with new innovations, but also as a means for personal development. Something that is good for the own profession is to introduce inter professional learning activities at an early stage of professional preparation to capitalize individuals positive attitudes towards their own and other professional groups.

Andersson (2012) clarify that radiographers' adapt low competence when working with patient in a state of shock and when they are going to identify patients' pain and pain reactions, probably related to a lack of knowledge. Related to this it is important to implement professional training early in the radiographers' education. To reinforce this lack of knowledge it is important to work with learning in basic and advanced levels both in theory and clinical practice. Further on the thesis indicates the importance of train the radiographer in critical thinking and that they must increase their using of evidence based practice.

Hillergård (2013) also illustrates that the radiographers' needs informal learning, based on digital information as PACS and other information systems, to support the new knowledge demands in work practice. It also shows that the informal learning itself was a key factor in the radiographers' digital workflow.

In order to structure the radiographers' knowledge demands and knowledge in use in the image production process, were parts of Blackler's theory used in the analyze process. Therefore descriptions of Blackler's theory of knowledge organization will be presented in the next section.

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. And he 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 in e.g. hospital organizations etc. Embedded knowledge comprises individuals' physical skills and mental skills, as well as organizations skills. These skills together make a complex mix of: interpersonal, technological and socio-structural factors.

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' uses 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 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 AND MATERIAL

5.1 ETNOGRAPHY

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). Hobbs & 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, 2007).

Ethnography often has a twofold aim. Firstly it aims to in detail describe a specific socialization, and secondly by using different theoretical tools to clarify the general within the socialization (Hammersley & Atkinson, 2007). 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 behavior. Different cultures have different rules; ethnographic research often focuses on these rules of behavior (Hammersley & Atkinson, 2007). 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).

5.2 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 behavior 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, timekeeping 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 programs, policy development and future research.

5.3 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 interviewees. 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, and 4) the learning area. The questions asked included, for example: Can you describe your professional role? What differences can you identify in the work? Who do you communicate with at work? How is the communication conducted and how does learning take place? To what extent is computer-supported communication applied? What kind of knowledge is most important in practice? How do you learn new things in the image production process? How do you determine that an examination is complete?

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 behavior 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. Lundberg and Bergquist (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 anesthetics practice (Smith et al., 2003). This study by Smith et al. (2003) was done through observations and semi-structured interviews with anesthetics staff in two English hospitals.

The interviews and observations were carried out in the following way:

Interviews

- Participation was voluntary.
- The informants were contact via email or telephone calls. They received concise information about the study in general and why the interviews.
- 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.
- 13 novice radiographers who had worked less than 1 year and 24 experienced radiographers whom had worked more than five years were interviewed (table II).
- 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.

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 one and a half to two hours. In total, the radiographers were observed for 50 hours (table I).
- In addition, departmental audit meetings and teaching sessions were observed.
- Detailed notes were taken during the observation period, and transcribed immediately afterwards.

Table 1: Amount of interviewed and observed hours as well as number of observed X-ray examinations

Sites	Interviews (hours)	Observations (hours)	Number of observed examinations
A (University hospital)	13h	10h	18
B (University hospital)	15h	11h	16
C (University hospital)	9h	10h	12
D (Region hospital)	6h	8h	9
E (Local hospital)	7h	9h	14
F (Private medical center)	4h	2h	5
Total	54 hours	50 hours	74 examinations

5.3.1 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 is 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 (van Maanen1988; Silverman, 2001).

5.3.2 Context and participants

In the following section, the radiology departments and number of radiographers included in the study are presented (Table II). The empirical fieldwork began in October 2003 and finished in May 2012. The sites chosen were three University hospitals digitized between 2002 until 2006 (A, B, C), one region hospital digitized in 2003 (D), one local hospital digitized in 2003 (E) and one private medical center digitized in 2003 (F). During this period of time, a total of 37 radiographers were interviewed and 25 radiographers were observed at six sites (table II). These six 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 university and community hospitals of varying size and also private medical center, 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.

The sample represented the population through inclusion of both academic and community hospitals of varying size and location mostly in the area of Stockholm and in the south of Sweden. Adoption of the digital technology and willingness to participate in the study were also other credentials.

Nine radiographers were interviewed and six were observed at hospital A, eleven radiographers were interviewed and six were observed at hospital B, six radiographers were interviewed and four were observed at hospital C, four radiographers were interviewed and observed at hospital D, four radiographers were interviewed and observed at hospital E and three radiographers were interviewed and one observed at medical center F (Table II).

Table 2: The sites and numbers of individuals involved in the study, both interviews and observations: 37 radiographers were interviewed and 25 of them were observed.

Sites	**Radiographers interviewed paper 1**	**Additional interviews paper 2**	**Additional interviews paper 3 & 4**	**Observations paper 1**	**Observations paper 3 & 4**	**Worked as radiographer ≤ 1 years**	**Worked as radiographer ≥ 5 years**
A (University hospital)	2	2	5	2	4	4	5
B (University hospital)	4	4	3	4	2	4	7
C (University hospital)	3	1	2	3	1	0	6
D (Region hospital)	3	0	1	3	1	2	2
E (Local hospital)	3	0	1	3	1	2	2
F (Private medical center)	0	0	3	0	1	1	2
Total	15	7	15	15	10	13	24

5.3.3 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 (2007) 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.

5.3.4 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, 2007).

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, 2004; 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, King, Rodden and Anderson (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 categories in the transcript, through content analysis. Polit and Beck (2004) define content analysis as "the process of organizing and integrating narrative, qualitative information according to emerging categories and concepts" (p. 714). Categories are the goal of content analysis, in order to increase the quality of the conclusions based on the results by relating to the categories (Graneheim & Lundmans 2004). Graneheim and Lundman (2004) describe content analysis as a common method to condense the data while still capturing the essence of the descriptions (ibid). According to Down-Wamboldt (1992) the content analysis, generates interesting and theoretically useful information with a minimal loss of information from the original in a systematic way (ibid).

Three work phases were identified in the analysis process: 1) the planning phase, 2) the performance phase and 3) the evaluation phase. The analysis showed that radiographers work with these three phases in both the analogue and the digitized environment. The interview material was firstly classified into the three work phases and the overall question it related to. In practice this was done through the application of color coding. The analysis showed that radiographers work with these three phases in both the analogue and the digitized environment. Secondly the interviews and observation notes were read several times in detail and the meaning unit were identified and highlighted. Thirdly a condensation of the meaning unit was done, which included shortening sentences without altering the content, it should be close to the original material. The sentences were here reduced to words or phrases and text that did not respond to the purpose was excluded. Fourthly the material was sorted into different groups which were related to the studies aim. Fifthly, the condensed meaning units' abstracts into higher logical level text units based on common meanings in the content and create codes of categories, which is grouped content that answer the studies aim. In the sixth and last step in the analyze procedure it was important to structure the material through identifying sub-categories related to a concept to bring order in the material. The common thread in the analysis session in this study was sought in the meaningful units, condensed units and processing of codes to identify sub-categories.

Table 3, illustrating examples of the analysis process, the first, fourth and fifth column is used to organize the result into a relevant "area" whilst the second, third and sixth column is used to refine the information to a higher abstracted level.

Table 3: Example of the thesis analyzes process.

Work phase	Phrase of meaningful units	Condensed units	Groups	Codes of categories	Concepts of sub-categories
Study 1) Evaluation phase	"It is easy to compare old images with new images. I can reflect if my new images are better than the prior made images''	Quality assurance of images in PACS	Digital Environment	Evaluation of digital images	Increased access to previous images
(Study 2) Planning phase	"The work is controlled by the patients booking time"	Rule-based structuring work	Reflective actor	Embrained knowledge	Static work
(Study 2) Performance phase	"Sometimes you just have to improvise; you can´t always do things by the book"	Do things through improvising	Reflective actor	Embodied knowledge	Problem-solving action
(Study 3) Planning phase	"…when it comes to children who are not X-rayed as often, I look through the entire manual step by step"	Learning through following manuals	Novice radiographers´	Novice radiographers learning strategies	Selective reading and information-seeking
(Study 4) Performance phase	"… you must not be afraid of trying something new, things will not explode"	Learning through competence and bravery	Experienced radiographers´	Experienced radiographers´ learning strategies	Experimenting combined with confidence and intuition

Study 1

A manifest content analysis was performed, which is about describing explicit content with as little interpretation as possible. Furthermore the study also had an inductive approach, which involves moving from the particular to the general point of view (White & Marsh, 2006). The analyze process enhance the interpretation of the changes in radiographers' work practice from analogue to digital technology, where three work phases were identified: 1) Planning phase, 2) Performing phase 3) Evaluation phase. Those work phases were chosen because the radiographers work with all three phases both in the analogue and in the digital environment.

Study 2

A manifest content analysis was performed, combined with an inductive and a deductive approach. The inductive approach relies on the various work phases 1) Planning phase, 2) Performing phase 3) Evaluation phase. The deductive approach involves an analysis from the general to the particular point of view (White & Marsh, 2006), this means that the analysis is based on a theory and makes an assumption about how the different elements relate to each other (Hiseh & Shannon, 2005; Polit and Beck, 2004). The deductive used theory was Frank Blacklers' Knowledge Organization Theory; embrained, encoded and embodied knowledge.

Study 3

A manifest content analysis was performed, combined with an inductive approach. The analyze process enhance the interpretation of the novice and experienced radiographers' learning strategies and critical thinking in the image production process, related to the first studies various phases 1) Planning phase and 2) Evaluation phase.

Study 4

A manifest content analysis was performed, combined with an inductive approach. The analyze process enhance the interpretation of the novice and experienced radiographers' learning strategies and critical thinking in the image production process, related to the first studies phase 1) Performing phase.

5.3.5 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 RESULT

Changes in knowledge and learning strategies pose a challenge in understanding and describing the interplay between humans and technology in an attempt to understand work practices. The technology used is without a doubt a crucial component in these practices. This technology is not an isolated factor, but an integral component that influences where, with whom and how to act, and what knowledge and learning strategies are needed to act. The results section in this thesis is based on four articles. The first article focuses on radiographers' changes in work tasks, while the second on knowledge with regard to the transformation from an analogue to a digital department. The third and fourth articles focus on novice and experienced radiographers' learning strategies in the digital image production process.

The results show that the planning phase has not been affected by advances in technology. However, the performance phase during which films are processed in development equipment, and images are produced and sent to a quality workstation for control, has been affected. The evaluation phase has undergone obvious changes, with radiographers checking image quality and sending patients home. Changes brought about in radiographers' tasks through the evolution from analogue to digital are presented in table 4.

Table 4: The changes in radiographers' work practice in the transformation from an analogue to a digital environment.

ANALOGUE ENVIRONMENT	DIGITAL ENVIRONMENT
PLANNING PHASE	
Use paper documents and films	*Use digital text and images, dynamic interaction*
Reads the paper request	*Reads the digital request*
PERFORMANCE 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 labeling 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 sreen (QC)*
EVALUATION 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*

Changes brought about in radiographers' knowledge requirements through the evolution from analogue to digital are presented in table 5.

Table 5: The changes in radiographers' knowledge requirements in the transformation 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 paper	*No change*
PERFORMANCE 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*
EVALUATION PHASE	
Embrained knowledge	
Check films/anatomy/image criteria	*No change*
No such requirement. Sometimes applicable on own initiative	*Analyze images/pathology/image projections*
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*

Technology shapes a department just as a department shapes technology. Changes take place when new technology is introduced in an organization. How individuals handle these changes is important information in understanding the outcome of introducing a new digital image production process. The difference in radiographers' knowledge application is presented in figure 2.

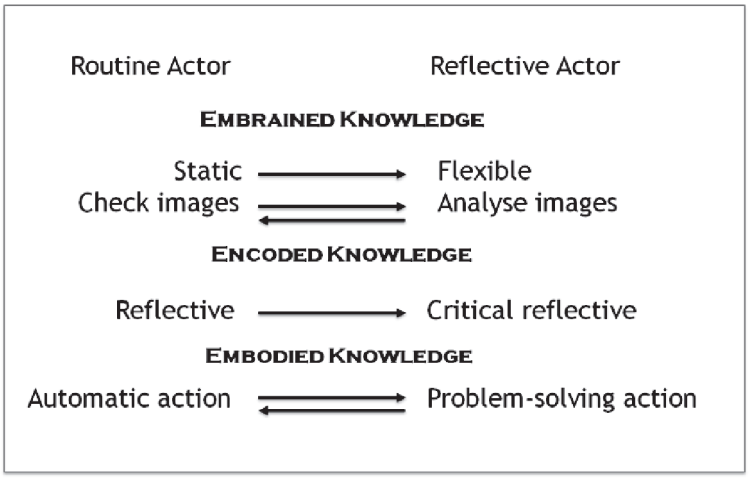

Figure 2. Summary of different components and levels, and properties of radiographers´ knowledge in use.

The results are illustrated by classifying radiographic work in 1) the planning phase; 2) the performance phase, and 3) the evaluation phase.

6.1 RADIOGRAPHERS' TASKS AND KNOWLEDGE IN THE ANALOGUE FILM PRODUCTION PROCESS

6.1.1 Planning phase

The work process for the radiographer in the radiology department begins when a request from another department/doctor reaches the laboratory. If the patient has old reports, the radiographers review them to facilitate planning of the new examination. The paper request specifies 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 that gives me a starting point in planning my work."

The radiographer reads the request and takes into account factors that need to be considered, e.g. if the patient is bedridden, or whether the patient is being treated in the hospital or through primary care services. The request may prompt the radiographer to ask questions, or review and store the patient information in a specific structured way. In this situation, radiographers apply embrained knowledge characterized by, for example, various prioritized tasks for different types of examinations.

This may include deciding on the sequence in which examinations should be performed, and setting priorities for film processing. Radiographers prioritize in different ways; routine radiographers have a more static approach, while reflective radiographers are more flexible in their thinking.

The knowledge required in terms of the radiographer's planning also includes the questioning, retrieval and storage of information, e.g. when retrieving documented patient data, and reading guidelines and manuals. This information is used to prepare and structure the film production process.

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

RIS forces the radiographer to question, read and store patient date in a specific, structured way. Before the patient is shown to the laboratory, the radiographer prepares everything for the examination. The patient is then shown to the laboratory by the nurse's assistant or the radiographer, and the patient's name and ID are double-checked.

All the interviewed radiographers knew how to fill out and review department documents and manuals (guidelines) in order to perform their tasks. However, this was done in a variety of ways, where some more or less checked-off items on a list while others adopted a more critically reflective approach when performing their tasks, working harder mentally and with deeper thoughtfulness.

6.1.2 Performance phase

The patient is positioned for the examination. This process becomes more complicated if the patient is immobile, either because they are unconscious or due to physical weakness. The film cassettes have been fetched and loaded. Once the patient has been positioned, the X-ray tube is focused, the focus size set and, if necessary, the tube angled for best projection. After the radiographs are taken and the film cassette has been exposed, the cassette is taken to the ID labeling machine and processed. No changes can be made to the resolution of the film after this as the film cannot be further processed. It is therefore very important that exposure data is properly set.

"…if anything goes wrong a new examination has to be performed."

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 RIS, recording who performed the examination, any drugs administered and changes or amendments to the examination codes. Radiographers apply action-oriented knowledge in performing an examination. It is knowledge that is 'in their hands'. This phase covers radiographers' knowledge pertaining to

positioning the patient for optimal projections in various examinations. It also includes radiographers' interaction with patients.

Routine radiographers performed the examination more directly from textbooks, while reflective radiographers applied their creative skills and emotions at different levels, and interacted with patients in a more thorough manner when producing images. Observations showed that radiographers combined their interpreted knowledge with their experience from knowing by doing in an individual procedure sequence.

It was not always easy for different types of radiographers to work together as they may not share the same preferences about the sequence in performing tasks. Reflective radiographers might apply their improvisational knowledge when unable to do an examination, while routine radiographers adhered strictly to the book. The more reflective radiographers demonstrated here their professional flexibility and their problem-solving abilities.

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

In the analogue environment, radiographers used their encoded knowledge when setting code parameters such as kV and milliamperes, applying their 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 objective of choosing different code parameters is to achieve optimal film exposure, but also to minimize the patient's X-rays dose by, for example, reducing exposure time (milliampere seconds) and manipulating voltage. 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 phase

All diagnostic work in the analogue department was done by the radiologists. However, when X-ray films were produced, the radiographers used their embrained knowledge to check the X-ray films. The first stage involves checking previous patient X-ray films when planning the examination. The second stage is after the examination, and entails comparing new and old films, and assessing whether the quality of the film is adequate for the radiologist. The third stage involves judging whether the old films, all or some, will be useful to the radiologist. This is done before the radiologists assure their diagnostic quality.

"...I need to review the examination after the examination is finished."

In the analogue evaluation phase the radiographers often reviewed the X-ray films and discussed them with the radiologists when needed. Patients were discharged after a radiologist had assured image quality. Paper documents, such as requests, are used to write messages to the staff—for instance, that supplementary images should be taken.

Communication between radiologists and radiographers is close in this phase. One interviewee commented:

"Instructions, if needed, were given by the radiologists to the radiographers by the light box…working in an analogue environment, light boxes are the meeting place."

Films were taken down and transported to the reading room where they were mounted by the radiographers or assistant nurses applying their 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 department. 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 RADIOGRAPHERS' TASKS, KNOWLEDGE AND LEARNING STRATEGIES IN THE DIGITAL IMAGE PRODUCTION PROCESS

The differences between novice and experienced radiographers' application of learning strategies in the digital image production process are analyzed in table 6.

Table 6: Novice and experienced radiographers' learning strategies in the digital image production process

NOVICE RADIOGRAPHERS´	EXPERIENCED RADIOGRAPHERS´
PLANNING & EVALUATION PHASE	
Memorizing combined with logical reasoning	*Memorizing combined with logical reasoning and predicting*
Active and attentive and listening	*Analyzing and demanding listening*
Asking questions and received feedback from colleagues	*Transforming knowledge through giving feedback and answering questions*
Straight forward and uncomplicated discussions	*Multifaceted discussions*
Selective reading and information-seeking	*Selective and validating reading combined with information-seeking*
Speaking out loud to themselves	*Not applicable*
Focused observations i.e. tunnel vision	*Situated discriminating to focused observations*
PERFORMANCE PHASE	
Memorizing combined with inquisitiveness	*Memorizing combined with a contextual perspective*
Repeating combined with perseverance	*Repeating combined with perseverance*
Doing and practicing combined with flexibility	*Doing and practicing combined with creativity*
Imitating	*Experimenting combined with confidence and intuition*
Receive information	*Receiving and adding information*
Not applicable	*Visualization combined with intellectual integrity*
Open-minded observation and communication	*Reflective observation and communication*

6.2.1 Planning and evaluation phase

Information and technology are used to prepare the tasks. One single patient may have several examinations scheduled. It is increasingly important to verify that the correct patient and examination have been selected in the PACS system. If not, the images may be transferred to the wrong PACS folder, making them hard to find in the system.

Novice radiographers' learning strategy in the planning phase involved memorization and logical reasoning. They showed awareness of new tasks in the image production process, and strove to remember what to do next time.

"I try to remember things precisely and sometimes it happens to be something that I remember from my school days. I also think about how to do things correctly, for instance how to plan positioning the patient?"

Memorization was also an important strategy in experienced radiographers' learning process. Experienced radiographers often chose to try out their own new ways of learning new things, and committed these methods to memory when the outcome was positive. Because of their experience, which enabled them to relate to situations in the past, it was possible for them to complement memorization with logical reasoning and predicting.

"When doing several examinations, you have to figure out in which order you should take the images…Sometimes someone will say 'do this instead' and then I think 'but I've always done it this way' because it has proven to be easiest for the patient.' Some things I cannot change, because my choice is easier for the patient and it will be faster for me."

Experienced radiographers had an approach that combined memorization and experiences.

The intervention with 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 department. There is a need for an increased high level of embrained knowledge to plan the examination working with PACS. Less flexible and standardized, the digital system is more controlled and requires the individual to know 'the way' to plan work in a given order. This means the system is forcing users to do activities in a specific way and order.

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

In this standardized and automatic milieu, the novice radiographers' learning strategy was to work alongside other radiographers. Radiographers learned from each other. When a more experienced radiographer narrated to a novice radiographer, the novice radiographer listened in an active and attentive manner.

"I listen to other radiographers during various conversations that may not be directly addressed to me, but that are important to me. When someone says 'this is how I usually do it' I tend to listen attentively and I interpret it to be based on experiences not found in books."

This means that narratives are important work tools in explaining how to implement best practice.

Experienced radiographers listened also to what the supervisors said, but they listened in a more analyzing and demanding way to reach the objective.

"I question a lot because I need to understand…Some things I just had to hear twice or three times ... when I hear something I ask 'what does this do?'. I have trouble accepting their suggestions if they cannot provide a reasonable explanation."

In terms of the radiographer's experiences, they had the opportunity to develop an enquiring attitude.

Further on, novice radiographers asked questions to learn new things and they received feedback when talking to colleagues.

"... I ask most questions when working in the CT laboratory. I ask how, why and when to use different buttons. Personally I have not really dared to experiment—you can't just press the button."

It is easier for novice radiographers to do new things if these new tasks have been communicated in advance.

Experienced radiographers learned when transforming knowledge through giving feedback and answering questions.

"...we have students and they are very eager to learn. We learn a lot from the students and the questions they ask."

It was important for experienced radiographers to have novice radiographers around them, because they were a key source for continuous learning.

Discussions with novice radiographers need to be conducted in a straightforward and uncomplicated manner in order to promote best performance.

"Sometimes when I'm working and encounter trickier cases, I can discover things I have not been confronted with before. It's then I need to collaborate by starting dialogues and discussions among colleagues."

Discussions need to be encouraged by management.

Discussions between experienced radiographers included how to apply standards and technology as well as planning for the patient's positioning related to the image production process. Radiographers also discussed the examination with colleagues and the diagnostic radiologists in a multifaceted way.

"When possible I discuss one or a few specific images with colleagues or the radiologist."

It is important to be able to communicate with people in different professional roles and work in an interprofessional manner. Interprofessional learning is an integral part of modern radiographers' tasks that has been a reinforced and important concept.

Encoded knowledge was needed for retrieving, transmitting and storing information in databases. 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."

Novice radiographers learned to structure their daily work by reading different kinds of documentation and manuals. When seeking information they selected key information in the text, or sometimes read step-by-step while planning their work.

"Sometimes I only look for a certain section in the manual if, for instance, I do not remember the projection or a preparation step. However, I review the entire manual step-by–step when it comes to children who are not X-rayed as often."

Novice radiographers also spoke aloud when reading different kinds of manuals and documents.

When the radiographers spoke aloud, they affirmed their own learning. It was important that manuals were up to date and that information on the intranet was relevant, helpful, systematic and logical so it could be found easily.

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

Experienced radiographers learned to structure their daily tasks by selectively reading different kinds of documentation and manuals, and by validating important information from various information sources. Experienced radiographers practiced advanced information seeking to plan their work.

"I read the referral first, including the radiologist's priorities, and then I look at the first image and check whether all is OK, so I can continue …If I cannot solve the problem with the manual, I Google, I search, I read a book or something like that. It is hard but very interesting."

Experienced radiographers were often not content with the information they received, and took information gathering one step further.

One result of transferring quality assurance of images from radiologists to radio-graphers 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 assures the images in more detail—this requires more time in image processing before I send the patient home; I send a lot of patients home."

Focused observation was one learning strategy for novice radiographers.

"I look at the image to see if there is something strange in it. If so, I wonder if this is good enough for the radiologist to read."

For novice radiographers looking at images, it was important to be able to conclude that the images were 'good enough' for the radiologist.

Experienced radiographers, on the other hand, easily shift from the whole picture to details, from discriminating observation to focused observation.

"Because I'm very interested in pathology and diagnosis when I look at images I read the referral carefully to see if I connect what I see in the images with the request in the referral. I keep thinking of the anatomy and the function for the patient. I ask myself how I can read the image to figure out what this is."

Experienced radiographers had a stronger focus on the diagnostic aspects in their approach to an examination. They made clear preparations on a detailed level to support and optimize the radiologist's diagnostic work, i.e. they tried to create the best starting point for diagnosis rather than simply performing tasks according to a certain protocol.

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. The entire examination process must therefore 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 tasks. Technology itself does not directly cause these organizational changes, but it does make it possible for them to take place. Changes are prompted by many intertwined factors—behavioral, organizational, and technical.

In the evaluation phase routine 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."

New responsibilities to quality assure images for diagnostic work in the digital department requires reflective radiographers, i.e. someone with even greater advanced knowledge of image analysis. The respondents describe it in the following way:

"Say I want to look at the frontal view of the spine to know which side the patient should lie on when I proceed and take the lateral projection … or if a specific angle is required in terms of the X-ray to get an angle between the vertebrae."

Reflective radiographers apply deeper embrained knowledge when analyzing images. This calls for greater knowledge about image criteria and anatomy. 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.

Standard 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.

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 the tasks. 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."

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.

6.2.2 Performance phase

As in the analogue world, in the performance phase the radiographer sets the various parameters on the control panel of the modality, including kilovolt, milliampere, patient size, and the chamber where the exposure area is selected, as well as the image size. One interviewed 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.''

Radiographers use embodied knowledge as if it were 'in their hands' and take a 'hands-on approach' that involves image taking techniques. The authors observed that routine radiographers often performed orthopedic examinations in an automatic way, while reflective radiographers used their improvisational knowledge. They also had a stronger focus on solving problems when performing the examinations (field notes).

A learning strategy in the performance phase that novice radiographers used involved memorization combined with inquisitiveness.

"…I look at the image to understand how methods and image analysis come together in practice."

They tried to remember theoretical knowledge from school days and apply this in their work in order to understand connections and the overall situation.

"I try to remember things from my school days, along with watching how experienced radiographers methodically carry out their work. Then I look at the image to understand how methods and image analysis come together in practice."

For novice radiographers it is important to memorize in order to perform according to theoretical knowledge. Novice radiographers memorize new things from a connection perspective. They apply this memorization in their learning strategy and strive to view the connection from a generic point of view.

The experienced radiographer's learning strategies was memorization combined with a contextual perspective. This strategy was related to his/her earlier own knowledge, experience and skills.

"My experience supports me when performing the examination. For instance, in a situation where I need to decide if a patient needs a compression or collimation of images, or when I decide in what order the images should be taken."

For experienced radiographers it is important to memorize in order to perform according to practical knowledge. Experienced radiographers memorize new things from a situational perspective. They apply this memorization in their strategy of learning and strive to view the situation from a specific point of view.

Because the digital image allows post-exposure manipulation—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 fetching X-ray films from the file room, previous images for the patient are retrieved from PACS. Working digitally has also introduced new tasks demanding computerized interrogated knowledge, e.g. sending images digitally from the preview screen to the quality control screen. 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 to minimize the patient's X-ray dose.

Experienced radiographers used visualization as a learning strategy combined with intellectual integrity.

"I'm trying to get an overall view and a mental three-dimensional image. Understanding the idea behind the structure… it's a bit like a stream of symbols, a structured pattern that I can follow when performing in practice."

The three-dimensional image is used by the experienced radiographer in the image performance phase.

In the analogue department films were hidden in cassettes so there was no possibility to decide whether enough images had been produced in this phase. A change when transitioning to the digital department 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.

Performing an X-ray examination in the digital department 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. New knowledge of the modality, PACS system symbols and signs are needed in the digital world. 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.

In this phase the radiology environment has radiographers who are clinical teachers in their profession and act as tutors to practically support novice and experienced radiographers in their learning process. For instance, novice radiographers apply open-minded observation and communication learning strategy in practice.

"During supervision I usually get to watch how they do something, while they explain to me what they are doing."

For novice radiographers, it is important to watch how experienced radiographers work in order to understand the role and rules for performing examinations that novice radiographers learn through observing other radiographers and listening to their narratives.

Reflective observation and communication, in which it was important to understand how the parts and the whole are related, was a practical learning strategy that experienced radiographers applied. This strategy was complemented with the asking of questions.

"I watch, I ask a lot, I read, I want to know why and how."

The importance of communication in the workplace cannot be underestimated.

The digital image produced can be presented on a preview screen to check that everything needed is included, before taking the next image. Preview screen imaging has limited image quality and is only intended for a general overview to help radiographers decide whether they need to produce additional images. Examination of the patient is always conducted as quickly as possible. One radiographer commented:

"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 radiographers have completed the examination, they send all

the images from the reading unit to the quality control workstation where the images are checked and aligned with RIS data. Radiographers apply their embrained knowledge and cognitive abilities when checking images.

In this phase the radiographer needs to make an active decision on the quality of the 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."

In the performance phase, the radiographers apply encoded knowledge when they review the quality of the images, and when they manipulate and refine images to optimize image quality at the image viewing station.

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

Radiographers performed examinations in different ways, according to the respondents. Reflective 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.

Experience helps radiographers to be bold, which means they dare to try things. This leads to experimentation combined with confidence and intuition.

"…you can't be afraid to try something new. Nothing will explode."

Experienced radiographers are aware that they need to try new things by themselves or they will not be able to keep up with advances and remain well-informed.

Routine radiographers could identify problems but not solve them. They work in an automatic way. For example, in the above situation, 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."

Novice radiographers learn common routines through imitating different professional categories.

"I try to do exactly as they did."

Imitation is an important learning strategy, which means that the novice radiographer engages in active filtering in order to focus on the delimited task.

The novice radiographers' learning strategy was also to take images over and over again, performing repetitions. They had to combine repetition with perseverance.

"When I perform quite similar examinations I learn from repetition—doing the same thing several times."

Some things need to be performed numerous times and over time they will improve. It is therefore important to let novice radiographers work although they do not have extensive experience.

Experienced radiographers' learning strategy also involved taking images over and over again through repetitions. They had to combine repetition with perseverance.

"You learn by doing. Just like driving a car, you must do it yourself, again and again."

Experienced radiographers also produce repetitive work. They are aware that this is needed to do high quality work. They consider repetition an important ingredient in work.

Another learning strategy for novice radiographers was doing and practicing combined with flexibility.

"If something is especially difficult, I first observe a few times and then try it myself. Simpler things I test immediately, but with support from someone who has done it before."

It was widely commented that the novice radiographer applied different learning strategies depending upon the difficulty of the task.

Radiographers with experience also learn through doing and practicing but combined with creativity.

"The key is to challenge yourself in order to understand how things work."

Doing and practicing gives radiographers experience needed in work.

Documenting the image production process, recording who performed the examination and any drugs administered, as well as changes or amendments to the examination codes is done in RIS the same way as in the analogue film department of digital images.

Novice radiographers need to receive new information 'step by step'.

"I need to get the information step by step; I cannot absorb large amounts of information simultaneously."

How novice radiographers receive information about new tasks is important to the radiographer's learning process.

Experienced radiographers receive and add information as well as make their own notes.

"I must make a note of some things, such as type codes, and number combinations. Eventually, I learn them by heart."

Experienced radiographers push themselves to continuously learn new things over time.

6.3 RESULTS SUMMARY

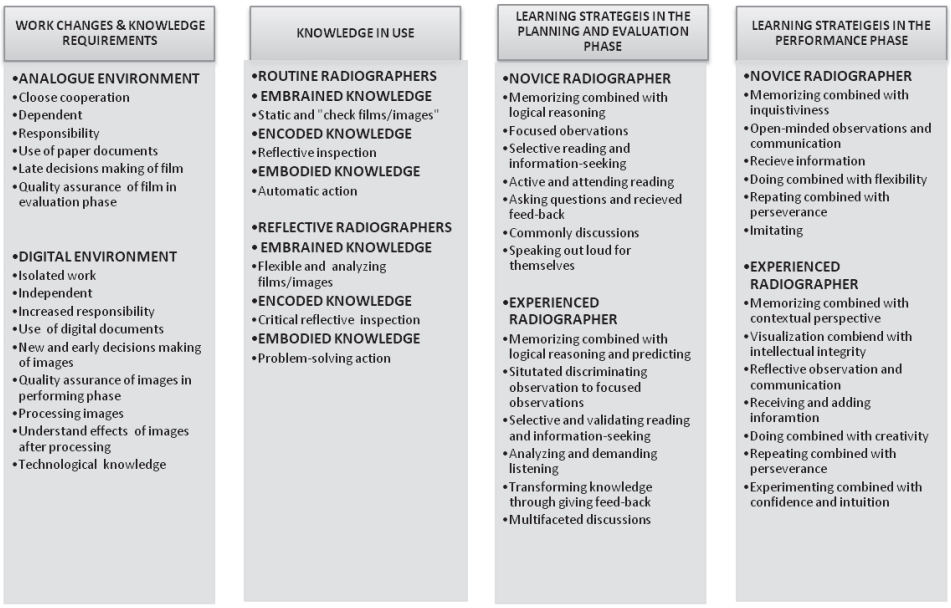

Figure 3. Summary of the thesis results.

7 DISCUSSION

7.1 RESULT DISCUSSION

The overall aim of the thesis was to inform the field of radiography of changes related to the digital image production process, by understanding how radiographers perform tasks and apply knowledge as well as learning strategies in work practice. Focus was also on the transition from novice to experienced radiographers in the digital image production process. When clarifying novice and experienced radiographers' knowledge and learning strategy differences, it leads to the opportunity to highlight possibilities that facilitates the transition from novice to experienced radiographers (fig. 4).

Figure 4: Shows that the addition of changes and differences is equal to possibilities.

7.1.1 Radiographers' tasks, knowledge and learning strategies in the analogue and digital environment

7.1.1.1 Planning phase

The study illustrates how the radiographer plans and sets priorities in the image production process. It also suggests that the planning process is very similar in the analogue and digital environment. The difference is, as Lundberg (2000) described it, that radiographers in the digital image production process prepare their work duties using modern technology. In 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— radiographers apply their embrained knowledge. As Blackler (1995) describe, embrained knowledge depends on peoples' conceptual skills and cognitive abilities. Marton and Booth (1997) have illustrated that actors can learn in various ways. These ways are either simple, memorizing the surface, or complex, requiring deep memorization. This is in line with the results of this study. It may thus be postulated that the best-practice profile actor acquires knowledge in similar ways that the routine actor acquires knowledge— by memorizing the surface, learning a simple way to perform a specific activity at a specific time. Meanwhile, the reflective actor memorizes deeply in a way where inherited knowledge can be applied beyond the specific activity for which it was initially intended. Surface memorization is primarily used to reproduce information, while deep memorization is used to understand the meaning of why

something needs to be reproduced. The learning that we acquire is stored like an archive in the brain (memory), similar to a hard disk in a computer. The storage in the brain is much more complicated than the data, because it is about human functions that are connected to each other in a variety of ways (Illeris, 2004).

Some radiographers were like routine actors, working in a static manner and following 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, clarifying 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, which 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 at all times. Maltén (1997) states that to achieve a reflective, insightful knowledge you need to have basic theoretical knowledge.

Other radiographers work like reflective actors do, setting 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, (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). This thesis has shown that radiographers apply critical thinking in their work, which may lead to new possibilities in practice. Studies show that radiographers have recently acquired more advanced responsibilities (Brown & Leschke (2012); Coelho & Rodrigues (2011); Hafslund, Clare, Gaverholt & Wammen Nortvedt (2008); Hogg (2004)) that are based on critical thinking as a core element. Critical thinking is thus a core in the learning strategy that enhances the radiographers' profession. Teekman (2000) studied ten non-routine nursing situations for the presence of reflective thinking. In complex situations, reflection included a variety of cognitive activities, including framing and self-questioning. Teekman (2000) identified three hierarchical levels of reflection: reflective thinking-for-action (what to do here and now); thinking-for-evaluation (integrating multiple viewpoints); and thinking-for-critical-inquiry (searching for ideas to develop the profession). In this study, these levels correspond to the following situations: 1) where the novice radiographer needs to examine a child in a situation that requires carrying out an unusual procedure, 2) where the experienced radiographer reads the images as part of the quality assurance process before sending the patient home, and 3) where the experienced radiographers read the manuals selectively and validate the information in order to makes decisions and improve manuals and documents.

is the contradictions in the meeting between different professional groups—operatives, technicians, production planners and salespersons—that fruitful learning environments can be created (Illeris, 2004). In this study, meetings between professionals do occur between novice radiographers, experienced radiographers, radiologists, nurses, and technical physicists although more meetings between different professional groups are shown to be warranted. In a Cochrane study by Forsetlund et al. (2009) they study the effects of educational meetings on professional practice and health care outcomes. They conclude that educational meetings alone or combined with other interventions has little effect. To increase the effects with educational meetings it should be combined with other different pedagogical interactions, e.g. feed-back (ibid).

Knowledge requirements for the radiographer's planning activities also involve encoded knowledge. Blackler (1995) describes this as conveyed by signs and symbols represented textually and digitally de-contextualized. Radiographers in an 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) in the environment to conduct their work in a reflective way. It is the reflective 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 improve' documents and manuals. Then they use their critical and reflective eyes and become even more deeply immersed in the manuals by getting personally involved. This thesis showed that the manuals did not always provide sufficient information on when, why and what to do. Both novice and experienced radiographers read the manual selectively and searched for information, but experienced radiographers also read the manuals more deeply, which was most important because the manuals needed to be improved over time. Backinger and Kingsley (1993) also emphasized the importance of having access to information about what one needs to know, what to do and how, and when to do it. This means that formal meetings to discuss complements to manuals, reading tips, etc. are most important for continuous learning.

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 in conjunction with this a clear statement about

standards and what to do if standards are not adequately met should be issued. Protocols should be archived, in a paper-based form, for lengthy periods in case of legal claims. The archived protocol should include the date it was in clinical use.

7.1.1.2 Performance phase

Technology has produced changes in the distribution of duties 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.

Hiebert, Gallimore and Stigler (2002) highlight the knowledge characteristic that is linked with practice; it is integrated and organized around problems of practice (ibid). In performing their tasks, 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 often involves image-taking techniques. Embodied knowledge is originally built upon information, and commonly described and presented in textbooks and thereafter interpreted by the individual radiographer. Finally, through experience, it becomes embodied knowledge. In this phase, knowledge requirements for radiographers involve being able to position the patient in different ways to develop images in different projections. Some radiographers work like routine actors do, making the examination in an automatic manner, directly from their textbook knowledge. Other radiographers use their creative skills and emotions at different levels when they produce images. Radiographers applied their interpreted knowledge in combination with experience from knowing by doing in an individual procedure sequence. It is important for novice radiographers to embrace learning strategies from experienced radiographers. One way to encourage this is as Hillergård (2013) suggests in her thesis: through mentorship with more experienced radiographers, with formal and informal meetings. Mentorship is distinct from a mentor. A mentor is defined as: "Trusted and experienced supervisors or advisers who have personal and direct interest in the development and/or education of younger or less experienced individuals, usually in professional education or professional occupations" (Ragins & Kram, 2007 pp. 129).Mentoring, on the other hand, is a relationship between a more experienced mentor and a less experienced individual for the purpose of helping, developing and socializing the adept (ibid). Mentors described personal and professional benefits for themselves as a result of undertaking the role of mentor. Although mentoring provided a number of challenges, including an increase in workload, the experience also enhanced their teaching and mentoring skills and contributed to their continuing professional development. While the role was more time-consuming than initially expected, this did not generally impact their ability to undertake continuing professional development or deliver patient care. In relation to the wider impact of the programs, some negative impact was reported on the service delivery

speed but not on practice quality. Mentors felt that the programs had a positive effect on teamwork and were beneficial for patient care. Some difficulties were noted in balancing the mentoring of trainee radiography undergraduates (Colthart, Mc Bride & Murray, 2010). Ragins and Kram (2007) consider that mentorship is mentoring with the addition that it can: 1) have any content; 2) be voluntary or mandatory; 3) be performed individually or in group; and 4) be applied through e-mentoring, when using new virtual techniques. Mentorship should be a self-evident part of radiographic work. This will foster the transition from novice to experienced radiographers.

Another way to transit novice to experienced radiographers may be through interprofessional practice. Stobbe et al. (2014) describe the definition of interprofessional practice as when two or more health professions learn with, from and about each other. In complex health care the interprofessional practice has been recognized as a promising solution to address these needs and improve patient care. Today it is common that interprofessional education is integrated in school curricula (ibid). It has been shown in this thesis that for radiographers it is important to be able to communicate with people in different professional roles and work in an interprofessional manner. However, less common are clinical education wards as described by Manninen (2014) and defined as 'a unit in health care settings, where the clinical education is carried out as collaboration between the educational institution and the clinical setting' (ibid, pp 12). Clinical education wards are units that train a group of nurse students with nurses as supervisors that include elements of interprofessional education to the extent that the students interact with several professions on the ward (ibid). The clinical environment in healthcare is complex, related to continuous changes, as e.g. technological development, new ways of working and reorganizations. These changes lead to the need of improvement, in order to reduce the gap between theory and practice, through introducing clinical education wards (Dapremont &Lee 2013).

Nonaka (1994) describes practical knowledge as 'knowing how': action-orientated knowledge of experience or hands-on experience, or practical thinking, while Hiebert, Gallimore & Stigler (2002) describes 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 practice-related issues. 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 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 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. 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. Reflective actors applied their improvisational knowledge when unable to do the examination as they used to do it or by the book. Here, radiographers demonstrated their flexibility in work and they needed problem-solving skills. They solved problems in different ways when doing an examination. In the digital environment, the knowledge requirement for performing their duties is that radiographers use their embodied knowledge. They use it in a similar fashion as in the analogue environment when they are going to perform examinations. How well the radiographer performs this activity differs: some are like routine actors who work automatically and do things by the book, following the rules. One of the novice radiographers' learning strategies in the performance phase was imitation. This coincides with Nonaka (1991) and Crossan, Lane & White (1999) who identified learning strategies. Both highlight that the first step in acquiring organizational learning to understand tacit knowledge is through imitation, observation and practice. In these cases it is important that the supervisors act as role models. Brammer's (2006) describe when studying nursing students learning in practice, that the best role-model system is when supervisors see students as future colleagues and support students learning and understanding, if the supervisors don't have this focus the students' learning may be poorly related to the supervisors attitude (ibid).The more reflective 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. One of the experienced radiographers' learning strategies in the performance phase was through experimentation. Nevis, BiBella and Gould (1995) conclude that when individuals learn from experiences, the more they can experiment, the more they will learn and the more they will tolerate errors. Vassalou (2001) describes that experimenting engages and develops individuals' creativity.

Applying embodied knowledge in a problem-solving manner was important in the analogue environment. It is equally important to have this perspective in the digital environment because radiographers work in a more isolated fashion. It is apparent that continuous learning is imperative for both novice and experienced radiographers in the performance phase. Learning strategies for both novice and experienced radiographers in the performing phase involved embodied knowledge, i.e. through doing, practicing and repetitions. Franz (2003) suggests that learning is an appropriation process of constructing or reconstructing. He refers to this as the two-fold learning approach involving 'learning by doing' complemented by 'doing by learning' (ibid). According to Lateef (2010), simulation-based learning can be the answer to developing health professionals' knowledge, skills and attitudes, thereby transitioning from 'learning by doing' to 'learning before doing'. Simulation can be done 'hands on' or using digital techniques. Other ways for radiographers to learn before doing is through training scenarios in clinical training centers. According to Halamek (2008), training scenarios are often coupled with debriefings and 'what went well and what went wrong' discussions (ibid). The goal for both simulation and training scenarios is to reach authenticity.

How do we teach individual radiographers to solve the problems at hand? To create the reflective actor it may be necessary to introduce some radiographers who can be mentors and

coaches to one another. To create radiographers who are problem solvers new subjects are needed in the radiographer education program. 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. A study by Alderson and Hogg (2003) indicated that examples of good practice include the need to base practice on evidence and peer practice. Clinical decisions in health care should be based on up-to-date, relevant and robust evidence. It is evident that there are more or less successful, useful qualities that the health care sector needs. Sackett's definition has been amended for the health sciences and allied professions. Evidence-based practice is used to describe all aspects of the discipline. When evidence-based practice (EBP) is translated for radiography, a definition of evidence-based radiography should be as follows according to Hafslund et al. (2008): *"Evidence-based radiography is radiography informed and based on the combination of clinical expertise and the best available research-based evidence, patient preferences and available resources"* (ibid pp. 5).

7.1.1.3 Evaluation phase

The study also illustrates the pronounced differences in evaluation tasks in the digital environment. The physical distribution of work, in combination with new tasks, 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 the UK released a statement on the delegation of radiological reporting distinguishing 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 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.

In some situations the radiographers view the X-ray films and make decisions in the analogue environment; the radiographers are using their embrained knowledge. Some radiographers work like routine actors do, and just check the film. Usually in the analogue environment the radiographers evaluate and reflect over the examinations together with the radiologist. Radiographers work like reflective actors do 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, helping 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 transformation 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 byproduct 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 have always done things. The perception that core values are changing is common when people talk about losing something in the change process. These feelings of loss frequently foster resistance to the changes (ibid). Pfeffer and Sutton (2000) argue that most organizations already know what learning is required to be successful, but often fail to act. According to Dodgson (1993) organizations seek enhanced learning for two distinct reasons. First, they may wish to maintain flexibility and competence in the face of rapid change and profound uncertainty in their environment. Change and uncertainty may arise from various sources such as technological evolution, economic disturbance, changing consumer expectations, or increased competition. Rather than implementing fixed responses to change, learning organizations seek to develop structures and human resources that are flexible, adaptable and responsive. Secondly, organizations need to learn in order to improve their capacity to innovate and hence to compete (ibid).

Markus (2004) shows 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 changes in how work gets done (ibid). Kafai and Resnick (1996) observed in their study that students preferred computer-based instructions which led to increased interest and curiosity. Further on, Malone and Lepper (1987) found that computer activities also motivated students because the computer allowed control, was accessible and interactive at all hours and allowed different levels of challenges. Corradi Fiumara (1990) believes that as we listen to someone's story, we are drawn into the unique reality of that individual. However, in our fast-paced and technologically sophisticated society, we may not

want to take the time to listen (ibid pp. 84). This thesis illustrated that despite productivity pressures, radiographers did take the time to listen. Novice radiographers spoke aloud for themselves and also listened to their colleagues in an active and attentive way, while experienced radiographers listened in a more critical way because they chose to whom and to what they wanted to listen. This means that it is important that managers clearly communicate that an important part of work involves taking the time to listen.

Evaluation tasks in the digital environment focus 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 radiographer's knowledge requirements then involve embrained knowledge. Radiographers who work like routine actors do just check the images, while reflective radiographers apply 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. Illeris (2004) defines constructivist learning as learners who construct their knowledge through analysis. Illeris (2004) distinguishes four different ways in which learning may be acquired: 1) Cumulative learning (do things without thinking), 2) Assimilative learning (add learning to previous learning), 3) Accommodative learning (decompose experiences and restructure them so that the new impulses may be absorbed), and 4) Transformative learning (new understanding). In this study the novice radiographers observe the manual in a focused and 'tunnel vision' way from A to Z. This is similar to the cumulative learning described by Illeris (2004). As the novice radiographer's experience and knowledge grows the novice radiographer will pass over to assimilative learning. The experienced radiographers, on the other hand, have an opened way to observe the manual, giving them the possibilities to think more critically and find ways of improving the manuals. In so doing, experienced radiographers pass from accommodative learning to transformative learning. In the context of reading images, this specific situation means deeper and more thorough embrained knowledge. 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). This thesis shows that feedback is an important learning strategy for radiographers' ongoing development of their competence and confidence. Novice radiographers were the group who often received feedback, while experienced radiographers transformed knowledge through giving feedback. Parsloe (1995) points out that it is of importance to reflect on, how to give feedback, and when and why to give feedback. He also notes that there are risks with feedback, related to cemented roles (ibid). Radiologists in Sweden have a quality assurance system named feedback. It is a web-system designed to support the identification and classification in radiology diagnostics, with focus on teaching and learning (Hillergård, 2013).

In the digital environment, however, all images are accessible for radiographers to process: the radiographer does not release any standard radiography images without first reviewing

them. This means they review their images more frequently today. The greatest difference between X-ray films and digital images is that X-ray films cannot be processed further, while digital images can be altered and manipulated in various ways. This thesis also illustrates the importance of offering novice radiographers a fruitful and strategic learning environment. They need to undergo comprehensive development to achieve optimal control of the totality and the safety of the patient. But it also illustrates the importance of having a strategic and fruitful learning milieu for experienced radiographers as they will continuously face new situations. Engeström and Sannino (2010, pp 5) defined "the theory of expansive learning focuses on learning processes in which the very subject of learning is transformed from isolated individuals to collectives and networks." In practice the expansive learning relates to individuals who learn something that is not yet there, that is new (ibid). This is what we would like to refer to as the strategic learning loop. It is circular as it is a never-ending process, and it is interactive as the experience and knowledge needs to be passed on to another person when you have acquired it. In practice this calls for extensive work cooperation. This means that it is likely that the departments with the best cooperative environment will also be the best performing departments. We argue that there is a difference between periods where knowledge produces the best results and periods when cooperation produces the best results. In our view we are in a period where the best practical results are primarily dependent on the departments' overall cooperative environment rather than on the expert knowledge that a few individuals possess. Cooperation is thus the foremost learning strategy for radiographers in practice today.

There are several pedagogical methods that may enhance how to transition from a novice and routine radiographer to an experienced and reflective radiographer that focus on the practical education. These are summarized in ten recommendations.

Recommendations for how to develop the transition from a novice and routine to an experienced and reflective radiographer

- Implement ***interprofessional education*** focusing on collaboration and teamwork between different professions
- Use ***clinical training centers*** with that can provide training scenarios
- Use ***simulation-based training*** for optimal experience of authenticity
- Implement ***Feedback***, a web-based communication system through tools such as MSN, Facebook, etc. to promote communication
- Implement ***clinical education wards*** to increase the number of radiographer students in practice
- Have a structured ***role model system*** that includes teaching material to provide guidance in tutoring students and novice radiographers
- Use ***mentorship*** to promote development of the radiographers' work practice
- Implement ***evidence-based practice*** such as collegial reviews to strengthen research
- Have ***educational meetings*** to encourage reflection in groups

7.2 METHOD DISCUSSION

In the present thesis the focus was to obtain a broad and a deep understanding of the changes of radiographers work practice related to the transformation from analogue to digital environment but also in the transition from novice to experienced radiographers. The combination of interviews and observations (study 1 to study 4) enabled this thesis to provide trustworthiness results. Trustworthiness includes concepts as: 1) credibility, and 2) dependability according to Lincoln and Guba (1985). To reach a high credibility in qualitative research several things need to be consider, for instance was the researchers approach important and it was also important that the researchers was familiar with the culture that would be research (Graneheim &Lundman, 2004: Shenton, 2004). This research has been performed in a correct and discreet way. The researchers were also familiar with the culture of the radiology environments, related to their earlier professions as radiographers, and to their professions today as was closed to the radiology environment. The credibility concept involved several choices as e.g. choice of context, choice of participants and also choice of data collection and methods. The analyze process and the result presentation was also including in the credibility. In this thesis the data were collected in different ways. The different forms of data collection formed a basis for the analysis, i.e. delivering a base from which categories and sub-categories could be identified. In all studies the research was built on voluntary participation, which raises the question of potential disadvantages concerning the variation of the participants. Therefore the informants were recruited from different types of hospitals, various experiences, different ages, and different genders. Because of the voluntary participation it is possible that every kind of experience has not been captured. The participant expressed and showed varies information concerning the research issues. It may be due to the participants' rights to decide when and how they choose to talk about the various types of question areas. Observations allowed us to see what actually happens in radiographers work practice, both analogue and digital, as well as between novice and experienced radiographers. The length of the 25 observations was approximately two hours per observation, which may be considered as a short time in ethnographic studies and can therefore be seen as a disadvantage. To turn this disadvantage to an advantage, it is of importance to highlight that the observations altogether were 50 hours, and that 74 X-ray examinations were observed. Another advantage was that the interviews and observations shifted in order, sometimes the interviews were done first, with follow-up observations, and in other cases it was the opposite, with observations first and follow-up interviews. These differences help the researchers to an open approach and a flexibility to the material. However, the 25 observations resulted in rich field notes, which together with the data from the interviews obtained a satisfying picture of the research issues. The methodological choice in the thesis, ethnography, was based on the aim and on the research questions.

The concept dependability has to do with the stability of the data; according to Shenton (2004) this was possible only through clearly reporting, to enable a future researcher to repeat them. In this thesis the data in each study were collected by one or two researchers, using

identical guidelines for questioning and observations, to ensure that the areas of interest were covered. The researchers who were doing interviews and observations were the ones who also analyzed and interpreted the data. The interviews led to a deep understanding over time and space, while the observations led to a more situated and detailed understanding. The combination of these data collection methods gave even more depth from the informants. Further on Shenton (2004) described that to reach transparence of the research process it was necessary to have continuous discussions with co-researchers during the process, in order to analyze the data from different perspectives, which this research was following.

8 CONCLUSION

This thesis concludes that since the digitized environment was introduced within the radiography environment, radiographers need to perform new activities, have new responsibilities and communicate in new ways. It also concludes that the role of the radiographer and knowledge requirements has changed in four principal areas: (1) communication in work, (2) image processing; (3) image quality assurance, including sending home patients, and (4) decision making. Furthermore due to the increased responsibilities in the digital image production process, radiographers need to be more reflective. Various knowledge components and learning strategies combined with training in critical thinking are suggested. The research illustrates that radiographers use embrained, encoded and embodied knowledge, aspects that seem to be important for understanding the effect of knowledge in practice. 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 reflective mind in practice – it is not enough to work in a critical way. Since the work is full of problem-solving action it is not enough to perform it adopting an automatic approach. Radiographers apply knowledge in different levels as routine actors or reflective actors, while novice and experienced radiographers apply the same learning strategies, but in different ways. It concludes that critical thinking is the core in learning strategy that develops the reflective radiographer. The novice approach critical thinking from rules and guidelines, the most important was to "not do wrong", while the experienced approach critical thinking in a more holistic and context-based way to solve problems. Knowledge of the differences in critical thinking approaches between novice and experienced radiographers may yield possibilities for fostering the transition from novice to experienced radiographers. It may be postulated that transferring the novice critical thinking approach into an experienced, new pedagogical methods in work are needed. Such pedagogical methods should be supported by for instance: e-Health services and system, evidence based practice in health care, mentoring, educational meetings, role-model system as well as inter-professional education. In addition, there may also be a need to introduce new subjects in the radiographers' educational program.

9 FUTURE RESEARCH

"The future depends on what you do today."
— Mahatma Gandhi

During the work with this thesis many new questions have been raised, e.g. how can we support the transition from novice to experienced radiographer through, pedagogical methods? What is the significance of novice radiographers learning outcomes when using feedback system, compared to traditional learning– differences and similarities? How can we support supervisors to develop the professional role of radiographers? Therefore the following topic areas need to be further explored: pedagogical methods in practice, novices learning outcomes in practice and supervisors' professional role. The pedagogical method must be obvious for all included employed in teaching and learning in practice. It is necessary to create possibilities for the learners by giving them: time, time and time. It is also important to highlight that supervisors should provide both challenges and support which are important parts of the learning process. To develop the supervisors' professional role, suggests both personal meetings, but also digital meetings. Hillergård (2013, pp. 43) concluded that "new technology, on its own, does not cause transformation of radiographic work - also the radiographer needs to transform". The questions and topic areas above could be a way forward to support the development of the radiographers' profession. The main focus on future research will be to follow up effects, impacts and risks when implementing and using new tools that aim to support the radiographers in their transition from a novice to an experienced radiographer.

10 TILLKÄNNAGIVANDE

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