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Informal Learning and Complex Problem Solving of Radiologic Technologists Transitioning to the Workplace

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1. Introduction

Knowledge use can be highly dependent on the judgment of professionals who translate "book knowledge" into practice. Practitioners use judgment and interpretation to create new knowledge suited to local circumstances. Some of this knowledge is unique to individuals, but often local knowledge is valuable if shared with others facing similar challenges. Knowledge use can be difficult under the best of circumstances. Professionals regularly take many human and technical factors into consideration when learning to apply what they know to new circumstances. Much of this learning is informal. It takes place on the job as professionals learn through and from their experience of using what they know to meet the needs of a range of unanticipated circumstances. Organizations can reap dividends when conditions support effective informal learning on the job. The consequences of not doing so can be seen in lost opportunities and ineffectiveness. In some settings, such as healthcare, life or death outcomes can weigh in the balance. In all cases, lost learning diminishes the quantity and quality of knowledge generated and shared, and as such, detracts from the goals of knowledge management.

In this chapter, we address the relationships between informal learning and knowledge creation, sharing and management in organizations. We first explore the social dimensions of knowledge management in relationship to the informal learning literature in order to examine potential links between the two with a focus on how professionals learn and generate new ideas or practices at work. We turn then to the heart of this chapter based on a multiple case study of informal learning and complex problem solving of radiologic technologists. This research provides an in-depth look at knowledge creation and sharing through the lens of informal learning.

2. Linking knowledge management and informal learning

A good deal of learning, especially for professionals, happens organically and informally as people tackle common challenges at work. The proportion of informal-to-formal learning in organizations is estimated at 70-80%, a ratio confirmed by several studies (e.g., Leslie, Aring, & Brand, 2003; Loweinstein & Spletzer, 1999; McCall, Lombardo, & Morrison, 1998). Knowledge management and informal learning are often examined in separate literatures,

yet there are important links between them. Conversation, social interaction and collaboration, relationships, and work-based learning practices form the heart of informal workplace learning. These practices are also key to conceptualizations of knowledge creation and sharing that emphasize its social dimensions and a constructivist view of what knowing means.

2.1 Social dimensions of knowledge management

O'Toole (2011) points to two main approaches to knowledge management, one that emphasizes "semantic knowledge retention in the form of databases" and a second that "emphasizes knowledge management as a social communication process" (p. 26). This depiction parallels the frequently cited classification of knowledge as explicit or tacit, although as many authors have also noted, both types of knowledge can sometimes co-exist in any given circumstance. Explicit knowledge is more easily captured and shared via IT databases and communication systems, whereas tacit knowledge is often not fully conscious or understood, and is shared through conversation, storytelling, nonverbal communication, and art or drama or other aesthetic experiences.

Nonaka and Takeuchi (1995) built their understanding of knowledge creation on the importance of converting tacit knowledge to explicit knowledge as a means of creating new knowledge in the workplace. Nonaka and Takeuchi (1995) purported that "tacit knowledge is deeply rooted in an individual's action and experience, as well as in the ideals, values, or emotions he or she embraces" (p. 8). They recognized two dimensions of tacit knowledge, the first being technical knowledge or "know-how" specific to a particular craft, and a cognitive dimension consisting of "schemata, mental models, beliefs, and perceptions so ingrained that we take them for granted) (p. 8). Van Krogh et al. (2000), building on these ideas, emphasized the difference between managing knowledge and knowledge enabling. The latter "depends on an enabling context" which they further define as "a shared space that fosters emerging relationships" that resembles "the Japanese idea of *ba* (or 'place')" which "is connected to …two points: knowledge is dynamic, relational, and based on human action; it depends on the situation and people involved rather than on absolute truth or hard facts" (p. 7). In doing so, they take a constructivist view of knowledge creation, that is, that people make their own meanings in interaction with one another in context. Constructivism is "postmodern" in that its adherents do not believe in an objective truth that is separate from the people who create it. Knowledge, therefore, is constructed and interpreted individually based on a person's history and experience, but knowledge can be shared because social realities often overlap and interact.

Cianciolo, Matthew, Sternberg, and Wagner (2006) describe tacit knowledge as "an adaptive intellectual resource stemming from the active interaction between individuals and their dynamic environment" (p. 617). A trusting environment is essential for this to happen. Building on Nonaka and Takeuchi (1995), Van Krogh et al. (2000) identify five key steps for knowledge creation: sharing tacit knowledge, creating a concept, justifying a concept, building a prototype, and cross-leveling knowledge (p. 9). They note that "managing conversations" is one of only two links that are common to all five steps. "Effective conversations," they continue, "allow for higher creativity; stimulate the sharing of tacit knowledge, concept creation, and justification; are essential for developing a powerful prototype; and lubricate the flow of knowledge across various organizational levels" (Ibid). Conversations take place in relationships and social interaction. Context — in particular a

supportive caring *ba*, conducive to trust — affects this kind of knowledge creation and sharing. In organizations, context is influenced by group and organizational structures, practices, climate and culture.

2.2 Informal learning

Similar ideas — constructivism, tacit knowing, meaning making through interaction with others, and the critical importance of context to learning that is highly situated — likewise permeate research and practice focused on informal learning. Informal learning is often defined in contrast to formal learning. It is organic, and typically motivated, directed and sustained by one's own intentions and interests. An online survey by The American Society for Training & Development and the Institute for Corporate Productivity of 1,104 human resources and learning professionals—managers, directors, vice presidents, or C-level officers in large enterprises operating in multiple nations defined informal learning: "as a learning activity that is not easily recognizable as formal training and performance support. Generally speaking, it takes place without a conventional instructor and is employee-controlled in terms of breadth, depth, and timing. It tends to be individualized, limited in scope, and utilized in small chunks" (Paradise, 2008, p. 53).

In 1990, drawing on work by John Dewey, Marsick and Watkins (1990) defined informal and incidental learning by contrasting it with formal instruction. Informal learning is intentional, although often highly tacit. Sometimes it is incidental, that is, an accidental byproduct of another activity. Incidental learning is not intentional, although the originating activity may be. It can be noted or not, recognized in the moment or not, processed through subsequent reflection, or often through less conscious processes involved in adaptive socialization. Conditions that might delimit such learning include ability to reframe one's understanding of a situation, as well as capacity for seeing a situation in complex or nuanced ways. Informal learning is enhanced when people are, and encouraged to be, creative in their thinking and approaches to challenges they face; when they proactively pursue interests and solutions to problems; and when they are able to step back and look at "why" things are as they are and how they can be differently understood. Marsick and Watkins (1990) proposed an enriched problem-solving model of informal learning that was heavily influenced by Argyris and Schon's (1974) double-loop learning, that is, learning that examines underlying assumptions, values and beliefs that influence meaning making. Marsick and Watkins' (1990) model started with deep probing of the situation in order to frame one's understanding of the challenge or problem, followed by identification and consideration of a range of alternatives. Learning typically occurs informally in these early phases, often in experimenting with solutions. A learning review follows action to learn from both intended and unintended consequences, and to plan for a new cycle of framing, experimentation with solutions and learning from results.

This early model emphasized the individual as learner. Marsick and Watkins, in collaboration with Cseh (Cseh et al., 1999), revisited this model based on a study of managers in Eastern Europe that revealed the central role of context to what and how managers learned. Marsick et al. (2009) further revised and expanded their model based on examination of newer scholarship: on implicit and tacit learning theory, emotions and intuition, collaboration and social learning, and the dominant role of context in informal learning. They concluded that while the outlines of their earlier understanding hold, individuals cannot learn without a rich, social climate and that they do so intuitively as well as rationally or consciously:

> Perhaps a better analogy for thinking about informal and incidental learning is an amoeba-like process, multi-dimensional in nature, consisting of iterative cycling back and forth among phases of the process—with frequent forays into conversation, work with other people, and exploitation of a wide array of resources, often Internet-based or technology-driven, that provide new stimuli for further inquiry. Typically, the learning process includes an element of collective learning as work groups struggle together to solve a problem or sail forward to creatively address a new challenge (Marsick et al., 2009, p. 591).

A discussion of professional informal learning is incomplete without mentioning Schön's (1983, 1987) seminal work on reflective practice of professionals. Schön distinguished between reflection-in-action, the insight and adjustment that often occurs intuitively and tacitly based on prior experience and practice; and reflection-on-action, the more conscious look back after doing something that leads to rational examination of what went right or wrong. Schön adapted the idea of a ladder of inference, often used in explaining double-loop learning, to professional learning in practice as the ladder of coaching. He examined the professional learning of architects, musicians, psychologists and others with this framework and showed how much professional learning occurs in action and through interaction with other people and with the materials of the situation as professionals think about the situation in light of their specialized knowledge.

Eraut (2004a) and his colleagues have extensively researched the informal learning of professionals —e.g., teachers, health care and social workers, engineers, accountants. Their studies show that professionals deepen situational awareness and sensitivity to organizational context; develop personal capabilities and learn how to work better in teams; improve role performance (e.g., leadership, supervision, crisis management, and supporting other people's learning); increase task performance capabilities (speed, fluency, skill range and complexity); improve judgment, decision making and problem solving; and gain and apply new theoretical knowledge and resources.

Eraut further deconstructs learning that takes place via "thinking" during professional work, showing that their informal learning takes place when:

- Assessing clients and situations
- Deciding what, if any, action to take
- Pursuing that action, and modifying along the way as needed
- Managing oneself while balancing time, resources, priorities, relationships

Eraut explores the tacit dimension of such learning, noting that sharing of tacit knowledge is a sophisticated process, in which social interaction and context play a prominent role. Through his research, Eraut (2004a) has also identified different "modes" of cognition at play in each of these situations:

- Assessing involves pattern recognition
- Decision-making involves instant, intuitive response
- Overt activity involves routinized action
- Metacognition involves situational awareness

Eraut (2004a) suggests that training and education neglect key steps needed for effective use of knowledge at work, especially pattern recognition and conditions that support testing and expanding knowledge on the job. Individuals, continues Eraut, draw upon accumulated "personal knowledge" in socially situated workplace learning "that enables them to think, interact and perform." Personal knowledge is holistic. It includes non-codified

"personalized versions of public codified knowledge …., everyday knowledge of people and situations, know-how in the form of skills and practices, memories of episodes and events, self-knowledge, attitudes and emotions . . . . it focuses on the use value of knowledge rather than its exchange value in a world increasingly populated by qualifications" (p. 264).

Using this framework, Eraut and colleagues examined learning that occurs during normal working processes to better understand how these capabilities are learned. Four main types of work activity accounted for a high proportion of reported learning in much of their research:

- *Participation in group activities* included teamworking towards a common outcome, and groups set up for a special purpose such as audit, development or review of policy and/or practice, and responding to external changes.
- *Working alongside others* allows people to observe and listen to others at work and to participate in activities, and hence to learn some new practices and new perspectives, to become aware of different kinds of knowledge and expertise, and to gain some sense of other people's tacit knowledge.
- *Tackling challenging tasks* requires on-the-job learning and, if well-supported and successful, leads to increased motivation and confidence.
- *Working with clients* also entails learning (1) about the client, (2) from any novel aspects of each client's problem or request, and (3) from any new ideas that arose from their joint consultation. (Eraut, 2004a, pp. 266-267)

Context plays a big role — the context of one's personal life as well as work and professional practice. Eraut (2004a) emphasized that professional learning at work is fraught with missed opportunities that in part have to do with changing circumstances, personal proclivities, group dynamics, work climate, and availability of resources. He emphasized: "a group climate for learning has to be created, sustained and re-created at regular intervals" and "when mutual learning is low and relationships are dominated by suspicion this has to be a management responsibility" (p. 268).

Marsick, Watkins, Callahan, and Volpe (2009) reviewed 39 qualitative studies of informal and incidental learning strategies. They found that in these cases, learning was integrated with work and daily routines, and triggered by a jolt, challenge, or surprise. Learning strategies involved trial-and-error, reflection in and on action, observation of others, engagement with others at work, and self-directed learning projects. Learning took place through an enriched problem solving cycle, often collaboratively with others. They concluded that studies support the importance of individual motivation, self-reliance and self-direction in setting and reaching goals, and in finding opportunities for learning that aids performance, and their own personal agendas. But the context of organizations — culture, structure, processes, practices — plays a key role in enabling or inhibiting the motivation, time, resources, expectations, and rewards for learning.

Fuller et al. (2003) — who with other colleagues have developed and used a Working as Learning Framework (WALF) to research learning at work over five years in a range of occupations and economic sectors as part of a broader study funded by the Department of Trade and Industry in the U.K. — underscore the situated nature of this kind of learning. Context is critical in their view of informal workplace learning: "We need, therefore, to start from an analysis of the organizational context and work process in order to uncover and unpack what is being learned, how it is being learned and by whom" (p. 5).

2.3 Summary of key ideas vis-à-vis health care professionals

Informal learning in some jobs and some organizations can be highly individualized, for example, when learners are entrepreneurs, independent problem solvers, valued for creativity, or work in contexts where unique solutions are required that do not need to conform to technical or scientific standards. Jobs of health care workers, by contrast, fall somewhere in between highly standardized, routinized work (such as that found in industrial and manufacturing settings) and highly individualized work calling for unique solutions to problems. Their work and learning are guided by a body of scientific knowledge built and tested over time, yet they apply their knowledge in circumstances that can be unique in that each patient brings his or her prior life and medical history, physical characteristics, personality, family / national culture and context to diagnosis and healing. Health care workers, moreover, work collaboratively in teams, so they are also challenged to learn from and with others, often under pressure due to pain and potential life and death consequences.

Literature reviewed on both knowledge management and informal learning shows overlap among some key ideas, especially when examined for relevance to this kind of professional learning on the job in health care settings. To sum up, knowledge management as a social communication process (O'Toole, 2011) takes a constructivist approach that emphasizes meaning making that is highly social and collaborative. Informal learning literature takes a similar stance. Both literatures show that an enabling context is key. Informal learning research shows that learning occurs in organic ways on the job and is integrated with work tasks.

As the study reported in this chapter will show, professionals learn to apply scientific knowledge continuously as they make judgments about new challenges in light of their own personal knowledge and prior experience. Much of their learning, however, depends on social interaction; and that, in turn, is influenced by social and organizational context. Knowledge creation and sharing is often tacit, yet there are opportunities — whether or not taken — to surface and examine tacit knowing both to "train" professionals new to the situation, but also, to take better advantage of collective wisdom that is specific to unique local history and context.

3. Study of radiologic technologists' learning and complex problem solving

Radiologic technology is the art and science of producing medical images of the human body for diagnostic purposes. Technologists work with patients and sophisticated computerized equipment to produce detailed representations of human anatomy, physiology, and pathology. In the performance of their duties, technologists are called upon to solve a variety of problems. Technical aspects of problem solving involve adapting examinations to individual patient needs, and trouble-shooting equipment and computer problems. Providing patient care and managing relationships with coworkers create non-technical and frequently ill-structured problems. The most difficult problems technologists face are complex in nature with technical and non-technical, well- and ill-structured aspects.

Prior to entering the profession, student technologists typically spend two years in a formal educational program learning the basic skills and knowledge essential to clinical practice. This education includes learning in the classroom, simulated laboratory experiences, and clinical experience in a medical imaging department. In the relatively short period of time

students spend in a radiography program they learn the theory, facts, and procedures needed to solve well-constructed or instrumental problems. However, this time period is not sufficient for the development of complex problem solving skills. The developmental process for solving ill-structured problems is relatively slow (King & Kitchener, 1994), necessitating a continuation of learning in the workplace. "…the increasing complexity of today's medical field has made it impossible for students to learn all that is needed by graduation" (Trad, 2009, p. 101).

3.1 Research questions and design

A research study conducted by Yates (2011) examined learning and knowledge sharing among radiologic technologists. The researcher, herself a radiologic technologist and radiography education program director, chose to focus on learning that followed postsecondary preparation as new graduates developed the capacity to negotiate the complexities of the workplace. As one research subject noted, "Actual work is quite diverse. It's nothing like what they teach you in school" (Robin). Findings from this study demonstrated that the workplace serves as an advanced practicum for new graduates, where real-life clinical situations help technologists develop a way of knowing that goes beyond the application of instrumental and technical knowledge. Yates sought to understand the nature of difficult problems encountered in clinical practice, to identify specific learning practices leading to the development of professional expertise, and to uncover workplace conditions that supported subjects' learning and enabled problem solving. Study results provide a snapshot of informal learning in a particular healthcare context that is confirmatory to earlier work by Eraut (2004a; 2004b), Marsick and Volpe (1999), Marsick, Volpe, and Watkins (1999), Marsick and Watkins (1990), Nonaka and Takeuchi (1995), O'Toole, (2011), Schön (1983, 1987), and Von Krogh et al. (2000).

The study's purpose was to explore the process of learning and development of skills used in solving complex problems typically encountered on the job. The research questions posed were: (1) How does experience inform radiologic technologists' capacities for solving complex problems encountered in clinical practice? (2) What similarities and differences exist in how radiologic technologists operating at different stages of cognitive development solve complex problems in clinical practice? (3) How do research subjects describe and understand the ways in which their workplace supports or inhibits the development of complex problem solving skills? A case study approach was used, with a volunteer sample of 22 radiologic technologists employed at six hospitals in the West Coast region of the United States of America.

3.2 Research methods

Both qualitative and quantitative data were collected for the study. Qualitative data consisted of (1) in-depth semi-structured interviews with technologists that included discussion of a reconstructed problem and hypothetical problem scenarios; and (2) brief semi-structured interviews conducted with at least one supervisor and/or manager from each of the 6 research sites about workplace factors and culture. Quantitative data were collected only from the technologists and consisted of: (1) a demographic questionnaire; (2) the independently scored Reasoning about Current Issues online assessment based on the Reflective Judgment Model (King & Kitchener, 1994); and (3) hypothetical problem scores derived from the interview data. IRB procedures were followed in collecting data to assure protection of human subjects.

Aggregated data from demographic questionnaires, RCI scores, and hypothetical problem scores were analyzed using SPSS 17.0 for descriptive and analytical statistics. The researcher sought to discover whether any relationships existed among the following study variables: years of experience, educational preparation, age, RCI score, and hypothetical problem scores. Linear correlation was used in bivariate analysis to estimate the Pearson Correlation Coefficient for relevant item pairs using one-tailed test of significance at 0.05. Analytical tests were performed to understand the relationship between the capacity for reflective judgment in the context of the workplace and patient outcomes as assessed using a rubric to analyze hypothetical problems posed to subjects during interviews. Qualitative data were inductively analyzed for themes and categories. Qualitative data were also used to examine results from statistical analyses.

4. Findings from research study

Results of the study provide detailed descriptions of the processes by which subjects learned to translate basic skills and book knowledge into the ability to adapt to atypical clinical situations. Study results included in this chapter focus on early challenges, learning practices technologists used to overcome those challenges, and workplace conditions that supported or inhibited subjects' learning. Pseudonyms are used in reporting all findings.

4.1 Early challenges

A portion of the interviews explored challenges faced by technologists at the beginning of their careers in medical imaging. Subjects were asked to think back to their first work experiences as a radiographer and recall what was most difficult for them. The most prevalent response related to the process of enculturation into a radiology department's ways of work, learning the facility's particular imaging standards, and the unique technical features of the worksite.

Wanda articulated this challenge well:

> Probably knowing the routine. You know, getting my techniques down. Different type of film, different type of cassettes. Just combinations of those kinds of things I guess…if I'm in a brand new place, knowing where everything is…like surgery or ICU… (Wanda)

Another frequently cited challenge involved developing the capacity to adapt radiography examinations to patients' individual needs. Jeffrey and George described their initial difficulties negotiating the complex aspects of the profession that defy formal, structured instruction in education programs.

> When I graduated my x-ray school I was – you know-Merrill's (Frank, Long, & Smith, 2012) by the book. Everything had to be perfect because that's what I was trained. And now [with]…five years as a tech you can kind of see yourself – I guess the word is – taking shortcuts maybe? Finding easier ways to do it – you know, there's not one correct way to do something. As long as you get the right picture. Little tricks of the trade, I guess. Just that and adapting to the hospital's way of doing things. (Jeffrey)
>
> … just being able to adapt to what the patient needed, you know in certain cases. At [X] we didn't have any kids so I didn't have any experience with kids. So then I'm working at outpatient clinics where I'm with kids so it was a little bit tough. You know, just to try and make it easy for them, without hurting them or, you know, causing them pain. And then, you just learn to spend a little extra time explaining it to them or playing with them a little bit before you can start the exam. (George)

Subjects also described difficulties with gaining comfort and competence in the surgical suite, learning to work collaboratively with other team members, and developing the capacity to work independently.

Teresa was challenged by the unique workplace culture she experienced in the operating room.

> I think one of the things I was a little nervous about would be when I'd go to surgery. And when I was working the C-arm in the surgery…they need things done perfect and right the very first time. "No, don't touch this. Don't touch that. Be very careful when you're maneuvering this equipment to make sure that you're not touching anything [in] that sterile field." So there's pressure there. (Teresa)

Kelly's transition from student radiographer to technologist forced her to learn to rely on her own judgment in clinical situations.

> Yeah, I think coming out of school that was probably one of the more challenging things is not always having the tech with me, you know? – to go, "What do you think about this?" You know? So it's like – I'm making my own decisions now. (Kelly)

4.2 Informal learning processes

Subjects were asked to describe specific learning experiences that helped them develop professional expertise. As they articulated their process for learning and discussed how they overcame early challenges, subjects described a variety of informal processes that occurred as they went about their daily activities at work. The sample technologists developed advanced problem solving skills mainly through encounters with actual problems in clinical practice rather than through formal training offered by the employer.

The workplace served as an important context that influenced learning. Technologists in the sample developed professional expertise in a number of ways within the context of the workplace. Challenges and supports offered there served to enable or inhibit subjects' learning. The opportunity to collaborate with a diverse group of peers was the most frequently cited enabler. Availability of resources and access to a helpful, approachable manager were also seen as important for learning and problem solving. Many subjects cited fear of making mistakes as obstructive to learning. Logistical issues such as poorly designed systems, lack of availability of "tools of the trade," communications issues between management and technologists, and obstructive co-workers were the most frequently cited workplace inhibitors.

Learning took place in the context of natural learning communities that fostered learning and knowledge sharing. Findings on radiologic technologists' learning practices support the four main types of work activities identified by Eraut (2004a) as giving rise to learning in the workplace: (a) participation in group activities; (b) working alongside others; (c) tackling challenging tasks; and (d) working with clients (or, in this case patients). Subjects frequently learned through collaboration with more experienced technologists, often through informal mentoring relationships. Learning often took place through reflection on work alone or with peers.

4.2.1 The significance of collaborative workplace relationships

Collaboration and group reflection were important for learning in varying degrees to the overwhelming majority of subjects. Technologists were more likely to seek help from peers for technical rather than non-technical problems. Subjects cited many examples of

consulting with peers for help with a difficult problem, solving problems together with co-workers informally on the job and more formally at staff meetings, reflecting on practice with peers, sharing knowledge, and working together as a team.

> You have to talk with other people in order to get things done, in order to get better at it. Definitely a community effort… I talk with a lot of my fellow rad techs. And how they solve their problems, similar to mine. I ask them if they've ever experienced that. And how would they figure it out – or how would they solve it? (Scott)
>
> …if we have something unusual, whether it's pathology or it's like, a way to take an exam or something like that…we'll share it.…"Hey, look what I did. Or look what the machine can do if we do it this way." (George)

…if I recognize that I can't solve the problem, given the first few seconds or the first minute or two, then I'm already thinking, "Who can I pull in to help me solve this?" I have the resources of my MRI tech whose got twenty years experience, my boss who's got twenty-five, thirty years experience, or a co-worker that may look at it from a different vantage point. (Richard)

> I find someone who knows more than me….Is there someone that either had this experience, dealt with this technical side of it, someone I can go to that may be able to help me? If that doesn't work I'll keep searching. (Lynn)

These technologists recognized the diversity of expertise among their peers, tapping these resources when presented with unique workplace challenges.

Carrie described the enabling learning culture created by her supervisor and manager at staff meetings.

> We can bring up anything. We have a monthly meeting and we can bring anything up at our meeting. And they always listen to us and we have changed things from talking about stuff. (Carrie)

For some older subjects who entered the profession prior to the digital age, computers (now ubiquitous in acute care settings) sometimes posed considerable challenges. These technologists relied on more technically adept peers for help with such challenges.

> …there are some peers that are like, right on the target with the computer. It's like their third hand. And they're also on day shift so they get a lot of the extra [training]…And when a new program pops up or when a program has been updated or PM'd – something doesn't jive with what it used to do – they're the people that are…usually the ones that are around during that and will see it first. And they go, "Oh, yeah, yeah, yeah. You just do this, this, and this." (Katherine)

Several technologists described work with particular peers as "seamless":

> …well, sometimes if you have a difficult patient we help each other out in doing the exam. Like one will position the tube, the other one will set the technique…it's weird…you don't really have to talk to each other. You just kind of know what the other one is going to do – and so it's just automatic. (Leigh-Ann)

Working side-by-side with others in trusting relationships facilitated learning and improved efficiency in completing tasks for a number of research subjects.

4.2.2 The importance of mentoring relationships

For the overwhelming majority of research subjects, engaging in mentoring relationships assisted in the transfer of tacit knowledge including enculturation into the imaging department's ways of work, and for learning the "tricks of the trade." Scott and Alex

described the roles their mentors played in helping them understand the culture of the worksite as well as the technical "know-how" needed in the development of professional expertise.

> …yeah, they kind of – told me how things work here and – kind of showed me the ropes, I guess you could say….They really listened to me, listened to my problems and – tried to truthfully figure out a way to help me…(Scott)
>
> …there's a tech who's now in special procedures. I think [he] was really instrumental in getting me to see – not just the technical but just kind of the attitude to have. Or the eyes to look through…because he doesn't let things really bother him a whole lot. And he knows how things should be but recognizes how things actually are…He taught me a lot of good habits. I worked with him in surgery a lot. And he always kept the equipment clean and well in repair. He kept his areas organized. And told me how I should behave with the staff in surgery. Because it's a different culture down there – what they expect and how to anticipate what they want. And that was a big help. (Alex)

In most cases, mentoring relationships were informal and spontaneous. Most often, more experienced peers served as mentors. Less often teachers, clinical instructors, supervisors, and radiologists mentored. Effective mentors exhibited the desire to teach, made themselves available to the mentee, were exceptionally competent and patient focused, listened and communicated well, and were kind and empathetic.

> She was amazing. And she had been a tech for, I don't know, eight or ten years…and she was just very – just you know – cool, even-tempered… Just really good at problem solving…she was just on it…at the drop of a dime knew exactly what to do…and she always had really good solutions. And it was really catered towards the patient. It wasn't like "Okay, we're gonna wrench you around because this is the way I know how to do it." It was like, "Oh, well you can't do that? Okay, 'cause I can do this." You know? No problem. (Kelly)

Mentors shared expert knowledge and acted as role models and coaches. They gave mentees time and space to work out problems for themselves, yet were available to help as needed. They worked side-by-side with the mentee as a team, asked questions to encourage critical thinking, and invited questions from the mentee. They also asked mentees to verbalize their thinking and at times tested or challenged the mentee.

> …they made me think out of the box, you know – It was like, "Here's a walkie-talkie chest. Okay, now here's this next one. Now, how are you gonna do this guy?" Rather than just going "do this, do this, do this." It's like, "Let's see if you can do it. If not, then I'll help you." Yeah, that's it. Made you think rather than just repetition. (George)
>
> Well, I think he let us do a lot of things on our own, whereas a lot of people would be kind of hovering and always giving their opinion right away, you know. "Oh, wait, what are you doing? You should do it this way." And he just kind of let us work it out…he gave us a lot of space. But he was always there if you had a question, "Oh, can you help me with this?" But he would always let us try and…he'd be like, "Why are you doing that?"…And so we'd have to kind of verbalize what we were doing. "Well, I'm going to – you know – position the plate like this so that when I shoot the cross-table lateral…" (Nicole)

As described by the research subjects, mentors displayed an exceptional capacity for articulating tacit knowledge. They seemed particularly adept in helping mentees develop the mental models needed to apply technical knowlege in innovative ways to unique clinical situations.

4.2.3 Other important learning practices

Other important learning practices included (a) deliberately working through difficult problems; (b) deliberate reflection on practice alone and with peers; (c) on-the-spot experimentation (as described by Schön, 1983; 1987); and (d) repetition of skills. A few technologists mentioned additional learning practices such as (e) observing peers' work; (f) engaging in dialogue with radiologists; (g) reading professional journals and other "trade" publications; and (h) teaching others. All subjects used a combination of practices for learning.

The first of these practices was *working through difficult problems*. Learning occurred just in time during everyday clinical practice, frequently involving "complicated" patient exams. Successfully navigating problematic situations helped subjects build confidence and develop competence.

> …for me it was just putting myself in every situation….If there was down time I would go find somebody who was doing something. I would go to the area that I haven't been in in awhile and…see if there was a case going on.…Just kind of put yourself in those positions and I would try to be as hands-on as I could. (Kelly)
>
> Like children and trauma situations…you're like "Okay" –but then you do it and you do it right and you're like, "Okay." You know you can do it. (Paula)

Katherine provided a detailed example of how she was able to complete a radiography exam by assessing a patient's emotional needs and working with her, building trust a step at a time to obtain the images needed by the ordering physician to diagnose the patient's medical condition.

> …a couple of weeks ago I was working x-ray and picked up a [requisition] and went up to get the individual in the waiting room…say the last name, they come up, we walk down to take the x-rays, and on her I was doing pelvis, bilateral hips, bilateral knees, and I think an ankle….Well, she was challenging. So I walked her to the room. And I confirmed her name and her birth date and what we'd be doing and she was immediately – even on the way walking like – "Doctors!" and she just went on and on about stuff that I don't even remember all of it because I was really trying to focus her to move forward. And so we got in the room and she was again saying she didn't want to take off her clothes and whatever she had on had to be OK - and she didn't know why I was here – and I was like, "Well this is your choice." She said "Well I'll do whatever." We started with the body part which was furthest away from having to do anything with clothes. I wanted to build up a rapport, get things on a better foot… So we got her on the table, lying down, didn't do anything by the hips, didn't do anything above pelvis even though she had, you know, zippers and whatnot….Went to the foot and heard all about that story….I got like, lots of stories from her….She was talking about not wanting to take off her clothes. I'm – "Okay, how about this? You're all covered. I've got you covered up. What you have is pants on that have metal on them." I said "I've got to take pictures there." I said, Would you mind…if we slide your pants down just a little bit? You don't have to put on a gown, you'll be covered."…so that's how I got through with it. (Katherine)

Teresa described the process of gaining competence and confidence through her experiences working in the surgical department, an area notorious for difficult personalities and a high level of stress.

> Oh well, you've seen it all. And you learn a little bit more about the doctors that you're working with. And the fear of messing up with certain doctors… once that pressure goes away…you're like "Okay, I know this doctor, I know how he likes things done." And

> speaking up for myself… "Okay, that guy can't come in here because he doesn't have [a lead apron] on." And I took my position a little more seriously. It took away some of the pressure because I could tell people what to do. It wasn't just people telling *me* what to do all the time. I could stand up and say "I'm in charge of the radiation here." (Teresa)

Nicole also shared her efforts to "find her voice" in the operating room, negotiating a way to command respect from the more difficult surgeons she worked with in the course of her duties as an imaging professional.

> We're talking about the OR. Yeah I mean like I guess that there's a lot of personalities in here and it's a tense situation so a lot of times we have issues communicating with the physicians, and there's a lot of anger that goes back and forth. And it's hard to know how to – I'm still working out how to…process that. And how to make it…so that I feel comfortable in there. I'm still doing my job, but I'm not being…stepped all over…and it's not every situation but you know… like as far as technically in the OR a lot of the doctors know what they want but don't want to communicate….They want you to anticipate what they want. I've just been trying to be more direct…. I've been trying to make eye contact when I can or just say, "Doctor so-and-so," and address them specifically. Because a lot of times they're – you know – "x-ray, da-da-dah." Like, I'm not a person, I'm x-ray. So I try and [say] "Oh, my name's Nicole." So that maybe they can [realize] that I'm a person…like I'm not just another instrument in the room that they can…throw on the ground. (Nicole)

The second important learning practice was *deliberate reflection on practice — alone or with peers.* Subjects recognized the value of reflection on practice, often describing a process by which they examined the results of their work (the medical images produced during an exam, or a patient's response to their care), made judgments regarding image quality or effectiveness of their actions, and made adjustments accordingly. Some subjects described solitary reflective activities, some described reflecting on work with a peer or group of peers.

Andrew, an exceptionally self-directed learner, described the deliberate process he developed for systematically reflecting on work following his shift.

> Sometimes I would go home after a day and I would think, yeah, there's that one or two x-rays that I think about, you know? Like maybe I should have repeated, you know? And then I would come and look at the report and see if the [radiologists] had anything to say about, you know, "image undiagnostic" or "unsatisfactory image quality" – sometimes that kept me up at night, thinking about those things. Now I've gotten to know the radiologists and their preferences more. I've gotten more comfortable with the equipment – the techniques that I need to know here. Because every machine is different so I've gotten to play with the technique a little bit here. I'm more comfortable with knowing what they consider diagnostic and what they would want repeated. (Andrew)

Leigh-Ann used a combination of reflection-in-action *as* she worked, reflection-on-action *following* her work, and collaboration with a peer to solve a problem.

> "Well, how am I gonna get this view if [the patient] can't do this?" And you're like thinking about it and then – you try it and it doesn't look exactly right. You would ask somebody, "Well, what do you think I could do to make this look better?" (Leigh-Ann)

Jeffrey reflected on the results of his work following an exam. His judgment informed future practice.

> …you're just kind of brainstorming- after the exam. Next time, if I angled [the x-ray tube] to the left or right or up and down, maybe I'd get a better picture… if it's a hard exam or if I had trouble doing it then I'll go back and think about it and "How could I make it easier next time?" (Jeffrey)

Kelly used a process of dialogue to reflect on practice with her peers.

> Even if I know I did something right, I still bounce it off of people because there's always something more that maybe could have been done or that I could have learned…"So then this happened and this happened."…It's more of a conversation for me – to just share the experience and then people will share their thoughts and ideas and whatever…about the experiences they've had and what they've done . (Kelly)

A third important practice was *on-the-spot experimentation.* A number of technologists described a process of on-the-spot experimentation as described by Schön (1983; 1987), utilizing real-time reflection to observe the results of their work and adjust their actions in response to feedback. This process represented an important way of learning to creatively apply theory to practice.

> "Okay, [the patient] can't do this. Then try this." And it's like, "Oh, I got a really crappy radiograph." Or, "The doctor can't see anything there." So that's not the way to do it in this exam. (George)

Alex described a synthesis of learning processes in the development of his practice: application of book knowledge, reflection-in-action, and observation of others' work.

> …sometimes I would think I know how to get a certain projection done because of what I learned from the book. Of course that's one of many ways to get it done. I would be frustrated when that one way didn't work. Well, I spent a lot of time experimenting, trying different ways. Besides what I had observed from other people and deciding for myself what I like. (Alex)

A fourth frequently used practice was *repetition of skills*. Some subjects mentioned repetition of skills as important to their development of professional expertise. This learning practice may seem passive and perhaps less important than the more deliberate practices uncovered. However, in actual clinical experience, repetition does not mean performing the same set of psychomotor skills multiple times in an automated fashion. Each exam represents a different set of problems to be solved due to individual patient conditions and the changing physical environment. Practicing problem solving skills by repetition helps technologists learn to respond to new challenges through innovation.

> I think it's just from repetition, keep doing things and you get used to it. And if I'm not sure how to do something I would ask the senior tech. And they would show me a better way to do it. …at first it was hard to do it a different way. Like if it was a textbook way compared to just doing it from experience. It's just like, I'm not going to get it if I try to do it like that. (Leigh-Ann)
>
> It's just the longer you're doing it – the more comfortable you feel because you know this is a medium sized patient, or this technique works well for this particular type of situation. (Wanda)

Fifth, in some cases, subjects described *observing peers' work.* Several subjects mentioned observing peers' work as one way of learning problem solving skills. This learning practice on its own is also relatively passive in nature.

> …some of the younger techs have a different way of doing something that – you've only done this way for many years, you know, so – I always like to watch and see…they did that, [and] I'll ask them…"How did you get that one?" And they go, "I do it like this." (Wanda)

As evidenced by the portion of the study focusing on characteristics and behaviors of expert problem solvers, observation of others' work must be followed by experimentation and adjustments in one's own practice if one is to develop professional expertise.

A sixth practice also identified was *engaging in dialogue with radiologists.* Andrew, a relatively inexperienced technologist exhibiting a high score on the problem solving portion of the interview, described the deliberate way in which he engaged in dialogue with a physician for the sole purpose of advancing his own knowledge and professional expertise.

> I remember one time when I first started I went into a radiologist's office and I said, "You know I'm a student. I'm looking to learn. Is it all right if I sit with you for maybe thirty or forty minutes, an hour – and just listen to you dictate?" And he said, "Absolutely." And he pulled up a chair right next to him.…And he would dictate and then he would stop in the middle of his dictations and he would point stuff out to me. And say… "This is why it's very important that you get the [costophrenic] angles. Because see this fluid here? If you had clipped that we wouldn't have saw that." And just pointing out every little thing to me. (Andrew)

A few subjects identified a seventh practice: *reading professional journals and other trade publications.* One subject demonstrated a high degree of self-directedness in his description of an application of knowledge found in a professional journal article to clinical practice.

> Like doing cross-table laterals with the hip on a DR [Direct Digital Radiography] wall Bucky. I read an article in a magazine, ASRT [American Society of Radiologic Technologists] magazine, and I tried it there. And I did okay with available time to do it– but one of the other techs on afternoons.…I talked to him about it and he showed me how he did it. And you know, it really kind of helped pull things together on how it works here with the room. (Frank)

Finally, occasionally, subjects learned by *teaching others.* Andrew told of another deliberate learning practice he engaged in for the dual purposes of helping others and advancing his own knowledge and skills.

> …after I graduated I went back to my school and volunteered so I was doing positioning class. So two days out of the week I would go to the labs and I would teach the new students positioning. I would go, starting with the hands all the way up to hips, pelvises – that helped me out a lot, I think…Because I figured if I had six months off and I didn't do anything it would be a little bit harder to get…back into the swing of things. (Andrew)

5. Discussion of study findings

5.1 Imaging departments as communities of practice

Yates' (2011) study subjects used a variety of informal practices to negotiate through and learn from early challenges they faced as new graduates of radiography programs. Subjects' learning occurred within the context of the work environment, through experience with everyday professional activities. The workplace served as the proving ground where technologists developed problem solving skills and professional expertise.

Many of the learning practices described by subjects in this research study involved hands-on experience with difficult problems and often included interacting, collaborating, and reflecting on practice with peers and other members of the health care team. Caring professional relationships enabled learning and problem solving for the overwhelming majority of subjects. These relationships served to facilitate the transfer of explicit as well as tacit knowledge among technologists within imaging departments.

Von Krogh, et al. (2000) emphasize the importance of a culture of caring for enabling knowledge creation.

Knowledge enabling includes facilitating relationships and conversations as well as sharing local knowledge across an organization or beyond geographic and cultural borders. At a deeper level, however, it relies on a new sense of emotional knowledge and care in the organization, one that highlights how people treat each other and encourages creativity-even playfulness. (p. 4)

Mentoring and collaboration, along with experimentation and reflection-on-action, helped subjects develop independent problem solving skills and the capacity for application of technical know-how to new clinical challenges. As described by subjects, medical imaging departments accessed for this study meet the criteria for communities of practice, defined as "groups of people who informally come together to exchange knowledge and experience in a shared domain of interest" (Cianciolo, et al., 2006, p. 623). Von Krogh, et al. (2000) use the term *microcommunities of knowledge* to describe "the small groups within an organization whose members share what they know as well as common values and goals" (p. 5). Cianciolo et al. maintain that communities of practice assist in the process of making tacit knowledge explicit and passing it on to new members. They emphasize the informal and spontaneous nature of communities of practice, in which members self-select for the purpose of developing capability and exchanging knowledge rather than completing a specific task. The communities of practice, or microcommunities of knowledge described by participants in this research sudy were not formalized or externally imposed; they arose spontaneously through daily interactions among members of the health care team as they went about their normal work activites.

Through participation in their respective communities of practice, research subjects were supported and challenged as they learned informally through experience in the workplace. A workplace culture that encourages collaboration and mentoring, allows time and space for reflection both alone and with peers, and provides a wide range of experience enhances informal learning and the development of complex problem solving skills in radiologic technologists.

5.2 Situating the study in the literature of informal learning

Marsick and Volpe (1999) assert that social interaction enhances informal learning, advocating for the design of work processes that maximize opportunities for sharing ideas and collaborating. Wenger (1998) argues "we cannot become human by ourselves" (p. 146) rather, all that we are as humans is based on our relationships and interactions in a social context. Brookfield (1987) views peer support as essential to developing critical thinking skills and emphasizes interpersonal relationships as a context for learning. Schein (1993) states that, "In dialogue, the whole group is the object of learning, and the members share the potential excitement of discovering, collectively, ideas that individually none of them might have ever thought of" (p. 44). In most cases, study subjects seemed to benefit from the diverse perspectives of peers with varying degrees of experience and problem solving capacities.

Raelin (2008) applies Social Learning Theory to work-based learning in the statement "…learners are active observers. In fact, people often learn behavior from observing others before performing the behavior themselves" (pp. 74-75). He asserts that in observing the performance of others, individuals make mental models or conceptual maps to assist them in trying out a skill for themselves.

Due to the nature of clinical practice, tackling challenging tasks usually involved working through difficult patient examinations alone or with another technologist. Marsick and

Volpe (1999), in a review of informal learning studies, reinforced this finding and noted: "Throughout the history of productive organizations, most workplace learning has been left in the hands of employees and has been gained through informal methods and through trial and error" (p. 2).

Davis (2009) substantiates the importance of learning events triggered by encounters with patients in the course of normal practice as one way medical professionals improve knowledge and skills. Schön (1987) begs the question "…how are practitioners to learn wisdom except by reflection on practice dilemmas that call for it?" Marsick and Volpe (1999) assert the importance of learning that occurs "'just in time,' as people face a challenge, problem, or unanticipated need" (p. 4). The value of this type of learning was recognized by many subjects.

Raelin (2008) defines reflection as "the ability to uncover and make explicit to oneself what one has planned, achieved, or observed" (p. 74). Vernon's (1999) study of informal learning and teamwork revealed the importance of reflection as a strategy for learning to be an effective team member:

> …only reflection allowed participants to form judgments about what was learned and to make decisions about current, future, and alternative applications of what was learned. They also used reflection to assess both the process and the outcomes of their learning experiences and of their interpersonal and trial-and-error experimentation. (Vernon, 1999, p. 35)

Some professionals in this study treated problems they encountered as a mix of what they already knew and new variations that required the ability to reflect-in-action, engaging in a process of real-time inquiry and on-the-spot experimentation (Schön, 1987). This process describes how technologists manipulate equipment and work with patients in a manner that is dynamic yet routine, utilizing tacit knowledge. When patient conditions or equipment problems present complications, the technologist executes "on-line anticipation and adjustment…continuous detection and correction of error," (p. 26) also known as "knowing-in-action." The technologist varies her routine by testing solutions and creatively solving problems in real-time to obtain diagnostic images of the patient's anatomy.

Marsick and Volpe (1999) observed that informal learning 1) is integrated with work and daily routines; 2) is often triggered by an internal or external jolt; 3) is haphazard and influenced by chance; 4) is an inductive process of reflection and action; and 5) is linked to the learning of others. Its value is often directly related to timing; people learn best in response to problems of immediate concern. Organizations can enhance informal learning by attending to specific factors: "Organizations…have to design jobs, work practices, and work relationhsips in such a way that people can talk with one another, collaboratively solve problems, and generally seek responses to challenges that they have identified, even if this does not fit into a preset work schedule" (Marsick & Volpe, 1999, p. 5).

Recent research on expertise and expert performance emphasizes the importance of communities of practice in the development of professional expertise. The central belief of communities of practice, based on work by Argyris (1993) and Wenger (1998) is that "because most of the relevant know-how that distinguishes different levels of expertise is acquired through experience, methods that stimulate the process of thinking about what one is doing and why, and talking about it with others, will facilitate the development of expertise (Cianciolo, et al., 2006, p. 623)."

Cianciolo et al. (2006) recognize a positive relationship between tacit knowledge acquisition and practical intelligence. They define practical intelligence as "the ability to acquire tacit

knowledge from everyday experience and to apply this knowledge to handling everyday practical problems in which the information necessary to determine a solution strategy is often incomplete (p. 616)"

Unlike general intelligence which tends to remain relatively stable throughout the lifespan, practical intelligence "is viewed as developing with effort and experience" (Cianciolo et al., 2008, p. 617). Practical knowledge is also seen as distinct from personality and motivation "because it characterizes a person's use of his experiences for learning and performance and not, in particular, his drive to succeed…" (Cianciolo et al., p. 617). Practical knowledge is domain-specific; in other words, context matters. In a review of recent research, Cianciolo et al. (2006) connect high scores on measures of tacit knowledge with higher levels of performance. There seems to be an intimate connection between the acquisition of tacit knowledge, practical intelligence, and professional expertise.

Cianciolo et al. (2006) maintain that communities of practice assist in the process of making tacit knowledge explicit and passing it on to new members. They emphasize the informal and spontaneous nature of communities of practice, in which members self-select for the purpose of developing capability and exchanging knowledge rather than completing a specific task. The communities of practice described by participants in this research sudy were not formalized or externally imposed; they arose spontaneously through daily interactions among members of the health care team as they went about their normal work activites.

5.3 Implications for "managing" and "enabling" informal learning and knowledge creation/sharing of technical knowledge in health care professionals such as radiologic technologists

Considered in light of the above, this study has implications for managers who assist technologists in developing advanced problem solving skills. Development — and knowledge creation/sharing — happen best when learners engage in real-life dilemmas in the context of everyday work activities. Providing appropriate workplace supports helps new graduates negotiate uncertain aspects of professional practice and assures that "seasoned" technologists continue to learn. As they learn, they appropriate knowledge resident in the community and organization, and potentially, they can contribute new knowledge as they discover and share new ways of doing things.

Research on informal learning (Marsick & Volpe, 1999) and the development of professional expertise (Cianciolo, et al., 2006) has identified ways for managers to facilitate learning that may also support knowledge enabling through conversations (Van Krogh et al., 2000). Yates draws conclusions about how this can best happen based on her study and these authors' work. The practices she recommends include:

1. Allow time and space for reflection on practice
2. Create opportunities for collaboration and group problem solving
3. Support mentoring relationships
4. Foster a safe atmosphere where technologists may learn from mistakes
5. Allow technologists to pursue solutions to self-identified challenges arising out of normal work activities
6. Encourage technologists to participate in policy-making and decisions affecting their work processes

Supporting technologists in these ways helps to create learning and knowledge sharing microcommunities within medical imaging departments. One application idea is to devote

a portion of staff meetings to developing technologists' problem solving skills. Technologists could anonymously submit brief descriptions of difficult problems encountered in practice. Managers could then present the problems to staff for a brainstorming activity. Utilizing small groups rather than one large group is suggested for this activity as people tend to feel safer sharing ideas and participating with only one or two others. A large group debrief could then conclude the activity so that ideas could be shared with everyone. This activity presents opportunities for technologists to learn from the collective problem solving skills of the group.

Managers may find that inviting technologists to participate in decisions and policy-making in matters affecting their work processes could potentially improve the quality of work, enhance technologists' learning, and promote the conversion of personally held knowing to publicly shared and tested knowledge. Participation may also have a positive effect on job satisfaction, productivity, and patient satisfaction. Managers are reminded that inviting participation is different from soliciting input.

Those involved in the design of physical space may also consider its effect on learning. A large centralized work area easily accessed from adjacent exam rooms may facilitate collaboration and group problem solving among technologists. Isolation of workspaces may discourage interaction and make it difficult for technologists to obtain immediate assistance in case of an emergency.

Managers may foster workplace conditions that enable a path toward professional expertise by supporting informal learning and knowledge creation / sharing in the workplace. It is important to note that informal learning was already being supported to varying degrees in the research sites at the time of data collection. By attending to learning and knowledge sharing in a more intentional manner, imaging managers can help to transform medical imaging departments into learning communities. "Such a community includes learning, not only as a matter of course in the history of its practice, but at the very core of its enterprise" (Wenger, 1998, pp. 214-215). Some components of learning communities may be formalized. However a caveat is that the effectiveness of these strategies may depend on "spontaneity, self-selection, or self-interest" (Marsick & Volpe, 1999, p. 8). Formal intervention could potentially negate their efficacy.

6. Conclusions

6.1 Relationships between informal learning and knowledge creation, sharing, and management

In this section, we look more broadly at what this study of radiologic technologists might mean for informal learning and knowledge creation, sharing and management. As emphasized in the beginning of this chapter, Nonaka and Takeuchi (1995) highlighted ways that tacit and explicit knowledge interact. Van Krogh et al. (2000) further emphasized differences between knowledge management and knowledge enabling. Knowledge is to be mined to advance a business's bottom line by improving productivity, innovation, and products or services that improve profit. As knowledge is created in the workplace, Van Krogh et al. (2000) emphasize that "new concepts must be justified according to organizational values, a knowledge vision, a business strategy, costs, return on investments, and so on. Through justification, unacceptable and unattractive concepts will be screened out" (pp. 130-131). Knowledge, therefore, is selectively created based on the organization's determination of what is profitable.

We suggest that knowledge creation and management for professionals in health care settings utilizes a different — co-equal and collaborative — process for determining what is or is not justified, acceptable or attractive. We turn to informal learning research among professionals for understanding why and how such knowledge creation differs even though there are parallels with work that has been done in the private sector to advance organizational goals. Professionals such as the radiologic technologists in this study also advance organizational goals, but additional benchmarks are used as well as criteria for successful knowledge creation and management. Knowledge is created and passed on via the profession to varying degrees depending on local conditions that enable or inhibit learning. Higher education programs could better prepare professionals by engaging students in learning practices known to facilitate knowledge creation and transfer of knowledge in the workplace. Collaborative partnerships between the two entities could enhance the process of turning locally created knowledge into useful "lessons learned" to be passed on to new as well as experienced practitioners. As importantly, knowledge created and shared may be valued locally for its own sake by the technologists themselves who are self motivated to develop their own expertise; and by the teams of colleagues who are individually and collectively motivated by the knowledge they acquire or deepen in their own pursuit of excellence.

Informal learning research helps to understand the mechanisms and value add for individuals who pursue knowledge and expertise development to meet personal and professional needs irrespective of what the organization demands. This research shows that much of the judgment and experimentation involved in adjusting knowledge and skills to best meet task needs is contextual and not highly explicit. For informal learning in technical professions, Eraut (2004a) suggests that "…tacit knowledge is more likely to be used for generating hypotheses or possible sources of action, which are then checked against other evidence or discussed with other people" (p. 253). Knowledge sharing among colleagues and through relationships often involves conversations, as Van Krough et al. (2000) also emphasize. But the goal for making tacit knowledge explicit and sharing it with colleagues can be both improved performance and the satisfaction of building one's own expertise and that of colleagues who have created a social and organizational climate where everyone gains through knowledge sharing.

6.2 Implications for knowledge-based systems in organizations

What implications does this study have for the role of knowledge-based systems that enable organizations to stay competitive, plan for the future and innovate? Knowledge creation and management strategies are not one-size-fit-all. They too are highly contextual. Knowledge managers and enablers need to carefully diagnose the context to best understand what most matters for success. They need support from the hierarchy to which they report to make changes to practices that can improve the climate and culture for effective knowledge sharing and learning. Some questions they might ask include:

- What mix of database management and social meaning making is key to success in that context?
- How motivated and adept are professionals at informal learning and knowledge sharing?
- In what ways is the social climate supportive of knowledge sharing?
- Do managers have the skills to facilitate learning and conversations that support knowledge sharing?

- Is time managed in such a way that professionals can reflect in and on action, and are encouraged and rewarded when they do so and share their expertise?
- To what extent is work organized so that it is normal and desirable to stop and ask questions when challenges arise?
- Are meetings and other formal gatherings designed to encourage open sharing and problem solving without blame?
- Who are the multiple stakeholders who screen, vet, and build knowledge in the organization and profession? What is their role, and how can it be clarified and enhanced to catalyze knowledge sharing?
- How can informal learning be enhanced in ways that better support, and take advantage, of knowledge technology?

This study has identified many ways that this occurs for radiologic technologists that are consistent with prior research on professional informal learning. Many of these studies have emphasized what individuals can best do to maximize their own learning. Yates' study adds insight into the social and organizational context that is critical in supporting individual informal learning and knowledge sharing. Health care institutions may not be able to control for the motivation and personal skills that individuals bring to work, but they can do much to affect climate and help managers who wish to enhance learning and knowledge sharing.

6.3 Limitations affecting our recommendations

Finally, limitations affect our recommendations because of the type of data and research designs of studies we have reviewed and examined in drawing conclusions. For example, Yates'(2011) study utilized a multiple case study approach, focusing deeply on the workplace experiences of a relatively small number of radiologic technologists. Qualitative data included in-depth interviews including discussion of reconstructed and hypothetical problems. Therefore, a limitation of the study relates to the self-reporting of subjects regarding learning processes used and invented solutions to the hypothetical problems. The researcher's direct observation of subjects solving actual problems at work might have more accurately assessed ability; however time constraints and patient privacy rules made this method impractical.

As many scholars attest, informal and incidental learning are challenging to research. Informal learning is highly tacit (almost intuitive, sometimes semi-conscious, and not explicitly articulated) and not easy, therefore, to observe behaviorally. Incidental learning is often unconscious until tapped. It is difficult to disentangle work and informal or incidental learning. It is not always clear how much of an outcome can be linked primarily to a particular informal or incidental learning experience. Many studies of informal learning, as well, are case studies, each of which uses a slightly different theoretical base for research. Many studies are qualitative and thus rely on perception and self-report. Many of these studies examine isolated critical incidents. Eraut (2004a) seeks to correct this focus on isolated points in times by conceptualizing informal learning from experience as holistic, and by drawing upon actors' full experience and capabilities as they interact with others and co-construct meaning at work.

Studies currently undertaken by Fuller et al. (2003) take a big step toward providing solid evidence for a systemic view of informal and incidental learning at work based on purposeful sampling of a wide range of businesses, large and small based on a common

Work as Learning Framework that they evolved over time based on literature review and research. Another promising approach is that developed by Skule (2004). "Rather than trying to measure learning directly" which is difficult because of its very nature, he sought "to identify the factors most conducive to informal learning at work" by conceptualizing the learning environment in the workplace." Skule began his research by interviewing 4-8 workers, managers or stewards for occupational groups in each of 11 different private and public sector enterprises in Norway, followed by a survey of 1300 employees in private sector and 200 public sector employees in Norway. Skule developed a measure of the learning intensity of work based on three factors:

- "Subjective judgement of how learning intensive/educational the job is"
- "Length of job-specific learning required to master the job"
- Durability of acquired skills, measured by how long it is possible to be away from work, and still remain professionally updated." (p. 10)

Further research that would test our thinking might involve mixed methods research of a sampling of health care professionals in a variety of contexts that utilize a common framework and take place over time that integrates insights culled from both informal learning research and knowledge creation, sharing, and management. It would be interesting to discover whether the learning processes identified in Yates' study of radiologic technologists are relevant to other types of healthcare professionals as well as for workers in other domains.

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Due to the development of mobile and Web 2.0 technology, knowledge transfer, storage and retrieval have become much more rapid. In recent years, there have been more and more new and interesting findings in the research field of knowledge management. This book aims to introduce readers to the recent research topics, it is titled "New Research on Knowledge Management Applications and Lesson Learned" and includes 14 chapters. This book focuses on introducing the applications of KM technologies and methods to various fields. It shares the practical experiences and limitations of those applications. It is expected that this book provides relevant information about new research trends in comprehensive and novel knowledge management studies, and that it serves as an important resource for researchers, teachers and students, and for the development of practices in the knowledge management field.

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