A Review of Literature: Learning Conditions of Radiation Therapists

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Background Operation of the modern radiation treatment center, with new and changing treatment technologies, raises questions about workplace learning of radiation therapists. The role of radiation therapists is directed by the organizational system, and changes affecting this role are made in response to changes in the field. Literature on adult education and workplace learning elucidates the learning process of radiation therapists.

Methods A comprehensive literature search was performed to develop a theoretical platform suggesting that continuous learning among radiation therapists is influenced by organizational factors, departmental culture, and technological advances.

Relevance Optimal patient care and safety demand comprehensive knowledge of current radiation therapy practices. Supervisors have described the need to “think on your feet” in an environment where peer-to-peer training is the method most often used to share knowledge.

Conclusion Although organizations attempt to enhance the learning capacity of all employees, the researcher found the opposite situation for radiation therapists today. Their learning opportunities are now fragmented and limited and adversely affect their problem-solving skills and clinical judgment. By extending existing research on knowledge transfer and knowledge management and by adopting a sociotechnical perspective, this study builds a theoretical foundation for this problem.
settings in some record and verify systems. To prevent such occurrences, a quality assurance program is recommended, which adds another dimension to practice.

Before the chasm between conceptual knowledge and clinical practice can be bridged, it is important to understand the impediments to workplace learning that radiation therapists now confront. This literature review examines deskilling among health care professionals, recent radiation therapy innovations, and selected theories on adult education and informal learning and knowledge transfer in the workplace.

Methods

The researcher performed a literature search of mainstream radiation therapy books and journals providing technical treatment delivery information. All of the publications, including those regarding adult learning, organizational learning, and knowledge management, were acquired using the education, management, engineering, and technology search engines accessed through the electronic library database at Texas State University in San Marcos. A search for supporting material also was collected through the ProQuest Dissertations and Theses database (ProQuest LLC, Ann Arbor, Michigan), which led to 2 dissertations. Key search terms included sociotechnical, technology, situated learning, tacit learning, explicit learning, knowledge transfer, organizational learning, systems learning, adult education, and workplace learning.

Literature Review

Deskilling of Health Care Professionals

Many social scientists have examined the effects of modern technologies on workers and society at large. In Labor and Monopoly Capital: The Degradation of Work in the 20th Century, Bravermann wrote that the introduction of mechanization and automation, in combination with modern management techniques, has led to the deskilling of workers in many economic sectors. The result has been a separation of the conception of a job from its execution. The traditional skill content of jobs was destroyed, and a homogenous, degraded working population was created.

Since Bravermann’s seminal work, concerns about the effect of technological changes and other factors on the practices of health professionals have emerged. Studies among physicians, nurses, and radiologic technologists have examined how technological innovations have adversely affected the skill sets and knowledge of these professionals. These studies include collaborative international research concerning communication, diagnosis, and other medical errors made during the process of entering and retrieving patient care information throughout hospital departments. The results of these studies offer insights into the effects of technological advances on radiation therapists.

Deskilling of Physicians

Ritzer studied the skills needed by physicians and other health professionals involved in diagnosis and how technology affected those skills. He found that medical technologies, specifically laboratory procedures and machines that aid in the diagnostic process, contributed to skill degradation.

Deskilling of Nurses

Rinard examined the effects of technology on nursing skills since World War II. She first analyzed the content of The American Journal of Nursing in 5-year increments to document the types of technological advances that had occurred during this period. These advances included new medical techniques and new drugs (1950-1960); new electronic machinery and specialized care units (1965-1981); and the introduction of new technologies to control, streamline, and predict care (1980-1996). Based on this classification of advances, she then analyzed how the nurse-authors responded to the technological changes. The separation of tasks entailed by the changes made many nurses fear that the hospital was turning into a “factory” and the nurse into a “technician.” Rinard also found that, as nursing moved into the realm of higher education, the differentiation between a “technical” nurse and a “professional” one depended on the ability of nurses to discuss tacit (how-to) skills in a social scientific jargon. She described changes in the nursing field as a deskilling process in the Bravermannian sense, making nursing “all hands, little head, and hardly any heart.”

Deskilling of Radiologic Technologists

Donahue studied the effects of new x-ray technologies on radiologic technologists. Her findings echoed
those of Ritzer, showing an increased division of labor because of separate licensing requirements for different machines. Some technologists work with mammography machines, others work only with computed tomography and magnetic resonance imaging machines, and still others are not allowed to use any of these machines. Along with the division of labor, new imaging technologies were believed to have limited the role of technologists in the imaging process, and thus could potentially alienate technologists from the work process and the product of their labor in the long term. Overall, the new technologies limited the skills of the technologists and were believed to have the potential to alienate them from the work process and the product of his or her labor in the long term.

**Technological Challenges of Modern Radiation Therapy**

Significant advances in both hardware and software have contributed to innovations in the computer-controlled delivery of radiation treatment, such as proton radiation therapy. The Midwest Proton Radiation Institute reports that dose distributions in proton radiotherapy are more sensitive to positional errors than those in conventional radiation therapy because of an additional dimension — depth. Radiation dose can be made to conform to the tumor to produce a beam that varies in shape to the same extent as the targeted tissue or tumor area in 3 dimensions. With multileaf collimation, very specific beam shapes consistent with the 3-D volume of the tumor may be produced. The high precision of beam shaping is reflected in the term “beam sculpting.” Using this sculpted beam, treatment plans require a very high radiation dose and smaller, stringent target-volume borders. Concentration has shifted from positioning the patient’s body to a more precise focus on organ movement — the fourth dimension in treatment planning. This illustrates the high degree of intended accuracy, where only the targeted tumor is exposed to a very high dose, leaving normal surrounding tissues unexposed to radiation.

To appreciate how a difference of only 2 mm results in rapid escalation of radiation dose, one must understand that treatment deviations with small field-size settings greatly affect the resulting dose output.

The effect of the output intensifies with smaller field sizes and higher energies, measured in megavolts (mV = 1 000 000 volts). A 2-mm increase in volume increases the resulting dose-per-monitor unit by 2% and 3% for a 2 × 2-cm treatment area for 6-mV and 18-mV energies, respectively. These are typical treatment energies. The same 2-mm deviation for a 1 × 1-cm area changes the resulting dose per monitor unit by 15% and 16% for 6-mV and 18-mV energies, respectively.

**Models of Workplace Learning**

Various models of workplace learning have been proposed that may be applied, in whole or in part, to the environment in which radiation therapists currently practice.

**Organizational Learning**

All organizations actively create, capture, transfer, and mobilize knowledge to adapt to a changing environment, whether adopting new technologies or expanding information networks. A key aspect of this organizational learning is the interaction of individuals across an organizational hierarchy. Human resource development initiatives, therefore, focus on the multilevel structure of an organization and on ways to target learning to its different workgroups at a level appropriate for each. In other words, the organizational hierarchy determines the types of organizational learning activities that occur, who may participate, and the extent to which new knowledge is shared. This model of organizational learning, however, has been criticized for several reasons.

Senge, in his critique of organizations in the United States, argued that the traditional authoritarian, hierarchical structure fails to tap the capabilities of all workers fully and to recognize their capacities for learning. The traditional notion that the top levels think and the lower levels act on their directives is no longer sufficient for effective management. Senge claimed that organizations must promote learning among all their employees on a regular basis to maintain cohesion among departments, especially in a rapidly changing environment. Because people learn not systems or management hierarchies Senge places the individual at the center of organizations.

In a similar vein, Brooks critiqued the “technical rationality” model of organizational knowledge and learning described by Schön in *The Reflective*
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Practitioner: How Professionals Think in Action.21 In Schön’s model, the learning of workers is tightly controlled and prescribed by those above them. In this hierarchy, scientists create knowledge, engineers and managers determine the ways to apply that knowledge, and semiskilled and unskilled workers enact the knowledge. In contrast, Brooks believes that knowledge belongs to the community as a whole, not to high-power individuals alone. The exclusion of low-power employees from the team-learning process, which is reflected in the cultural patterns of organizations in the United States, has serious implications for organizations competing in a diverse, technologically complex, and quickly changing global environment.18

In her critique, Brooks also emphasized the importance of critical self-reflection to all learning (ie, allowing individuals to examine their suppositions as they acquire new knowledge).18 According to many researchers, learning in context or in action is also important. These researchers18-22 asserted a direct relationship between participation in learning activities and professional role, identity, and practice. They all emphasized the interdependence of all hierarchies of employees within organizations.

Studies of knowledge transfer have focused on the interrelatedness of individuals within organizations and organizational factors that promote or impede learning. One factor is the willingness to share knowledge on a peer-to-peer basis. Another factor is the value an employee attributes to the training he or she receives. Burke calls these factors “transfer climate” and “utility of training” and argues that the linkage between these motivational variables and knowledge transfer outcomes need to be confirmed.23 In their evaluation of knowledge transfer in the context of human resource development, Kozlowski and Salas proposed a “levels of analysis” perspective to capture the interrelatedness of individuals, interventions, and organizational factors separately while maintaining the integrity of the system as a whole.24

Relevance to Radiation Therapists

The role of radiation therapists is controlled by various sectors within the hierarchy of the organization that employs them. Because radiation therapy departments are also hierarchical, various factors affect the continuous learning of radiation therapists as a work group in a technologically complex and ever-changing work environment (see Figure 1). Although the goal of organizational learning is to increase the knowledge of all employees, the learning opportunities of radiation therapists have become limited as their role within the departmental hierarchy has become more restricted. Controlling the flow of knowledge, limiting opportunities for learning, and restricting participation can affect the problem-solving skills, clinical judgment, and professional identity of radiation therapists.

Systems Learning

From a systems perspective, the roles of employees within organizations are directed and driven by the organizational system (ie, the whole), and changes affecting their roles and functions are implemented as a response to changes in an industry or field.25 In other words, the organization adapts internally to the pressures of external change; this adaptation, in turn, initiates the shifting of technologies and knowledge within the parts of the organization. Patton describes thinking within organizational systems as being focused on the whole while disaggregating the parts.25 In other words, the roles, functions, and behaviors of the parts are deconstructed and viewed only in relation to the whole. Senge believes the parts of organizational systems to
be so interconnected and so interdependent that any simple cause-effect analysis within such systems distorts more than it illuminates. Consequently, learning within organizational systems or systems learning presents unique challenges.

Relevance to Radiation Therapists
The role of the modern radiation therapist is directed and driven by the whole; thus, the radiation therapist’s role changes in response to industry changes. Radiation therapy practice has been redefined within the hierarchical system of other departments that direct the radiation therapist’s work and control access to information through changing information networks and changing technology. The learning activities, individual participation, thinking capacity, and even professional identity of radiation therapists are interdependent on other parts of the organizational system.

Situated Learning
Situated learning theory holds that the identities acquired by participation in communities of practice are continually evolving and are framed by the opportunities available within each community. Communities of practice refer to skilled groups, both professional and nonprofessional, that model an apprentice-to-master learning and working relationship. It is within these communities that individuals gain knowledge, progress through improvised opportunities from peripheral to full participation, acquire advanced skills, and assume the identity of a practitioner — all while gradually conceptualizing the practices of the community. Although participation is central to situated learning, many researchers agree that power dynamics within the workplace can adversely affect the participation of workers and that limited participation may prohibit workers from developing identities and practices unique to their roles.

All types of learning require that we understand who we are and what our maximum potential is, and we must learn to speak and act in ways that make sense to the communities in which we live. Lave and Wenger describe this process as becoming “a whole person acting in the world.” Although sense of self plays a role, practitioner identity is acquired through the collective recognition and validation of the individual’s actions or practices by others within the community of practice.

For this reason, Wenger considers practice in the context of situated learning to be a social phenomenon. Ibarra, from a social learning perspective, explained that situated learning also allows individuals to experiment with the practices that define their professional roles. They may adopt or adapt new practices based on the social context that provides structure and meaning to what they do.

Relevance to Radiation Therapists
Situated learning theory supports the supposition that the separation of radiation treatment planning, simulation tasks, and other forms of treatment preparation in the clinical workplace has marginalized the participation of radiation therapists. When work processes are separated into specific tasks and participation is limited to only a portion of a process, the interdependency of the employees who perform the separate tasks is greatly diminished. In this context, new generations of radiation therapists are unable to acquire the fund of knowledge and complete skill sets of their predecessors.

As specialized workstations and treatment consoles are introduced in the modern radiation treatment center, therapists are in jeopardy of becoming machine operators as a consequence of their fragmented job duties. They also are in jeopardy of losing their professional status and credentials because of their diminished job role and peripheral participation in the radiation treatment process. These current conditions restrict learning and severely limit the potential of radiation therapists as “therapists.” Their inability to rehearse, participate, and practice applications that actively link conceptual knowledge to their clinical work adversely affects their professional practice and identity and represents a significant step backward in the evolution of the credentialed radiation therapist.

Knowledge Management
The concept of knowledge management learning is embedded in some definitions of situated learning and is described with terms such as “knowing in action” and “knowing in practice.” The ability to perform daily tasks is achieved by acquiring knowledge of work processes. The concept of “knowing” connects the views of Lave and Wegner regarding professional practice with Schön’s concept of “knowing in action.”
As a result of changes in treatment practice spurred by new technology, staff as well as students are seeing, doing, and understanding less. Staff and, consequentially, students may be less able to demonstrate, practice, or rehearse the ability to connect treatment practices with higher-level thought processes and critical thinking applications regarding treatment rationale. This trend has been described in historical publications in which the clinical setting is increasingly characterized as incorporating fragmented operational knowledge through simplified tasks. As modern radiation therapists may learn new treatments by the “see one, do one” method only, new knowledge in this manner is void of the “knowing” element described by Polanyi and restricts awareness to the subsidiary awareness level. The more experienced radiation therapists have a richer stock of background and foundational knowledge gained from the previous “old school” years of application practiced through their work activities. The notion of “button pushers” — the potential degradation from “therapist” to “technician” — results from this subsidiary awareness phenomenon where the scope of learning remains limited to machine operation. Knowledge sharing among peers remains restricted to tacit knowledge, or “know how,” with less “know why” articulation ability.

Polanyi’s work suggests that continuing on this course of deskilling will lead to reduction in certain knowledge transfer among staff, with no conceptual recall and failure to rehearse simple application of concepts. Sociotechnical Systems

The constructs of the sociotechnical system were established in the context of labor studies by the Tavistock Institute in London and the work of Trist et al in the 1950s. Trist suggested the term sociotechnical was first suggested by Trist to describe a view that emphasizes the interrelatedness of the social and technological subsystems within an organization and the relation of the organization as a whole to the environment in which it operates. In other words, “the sociotechnical system view contends that organizations are made up of people that produce products or services using some technology,” and that each “affects the operation and appropriateness of the technology as well as the actions of the people who operate it.” As technologies assume more work functions, humans abandon
Much research on sociotechnical systems focuses on information systems design and implementation. Because modern health care systems are so dependent on complex human organizational structures, they are suitable to sociotechnical analysis. Although information technologies seem to be crucial to the development of sustainable health services, every new health informatics application seems to generate an unanticipated consequence that may adversely affect patient care. A similar technological systems situation has become a primary concern with modern computer-assisted radiation treatment delivery systems.

**Discussion**

Radiation therapists work in a fast-paced, ever-changing environment that poses many challenges. As they have been empowered by sophisticated automated technologies to provide more precise treatments, a critical perspective resting on learning theories assert that their tasks have become fragmented and their clinical knowledge jeopardized. Their function as caregivers is being appropriated by the very treatment delivery systems they now use. The mechanics and operational aspects of radiation delivery have, in effect, removed important elements from treatment that once fostered and demanded conceptual knowledge. Organizational structures and work processes also have been a limiting factor.

Maintaining competence in this highly technological environment is an ever-present demand for radiation therapists. What competence level is required depends on the expectations set by the immediate workgroup of radiation therapists but more likely by the organizational (or departmental) hierarchy. Expectations with regard to conceptual knowledge also vary, being strongly emphasized in some departments and less so in others. Radiation therapists customarily seek to maintain their competence by attending off-site continuing education programs, in-house clinical workshops, and on-site application training sessions or in-services. Peer-to-peer training, however, is the method used most frequently to share knowledge among radiation therapists who rotate between treatment machines. Anyone may seek training by his or her own initiative.
This paper presents the argument that forms of technology and automation create distance between treatment processes and forms of thinking and awareness. Even if manual procedures are no longer performed, radiation therapists still should maintain adequate conceptual knowledge, strong critical thinking skills, and independent clinical judgment. Nevertheless, as the researcher has argued, the ways in which technological advances have changed the practice of radiation therapy raise questions about how critical thinking and independent judgment can be fostered among staff radiation therapists within a system that fragments knowledge. The theories of workplace learning offer insight into the underpinnings of this phenomenon and have implications for the modern, technology-centered practice of radiation therapy (see Figure 2).

**Implications for Continuous Learning**

Historical reviews of medical practices and studies of health professionals show that the clinical setting increasingly is characterized by simplified tasks that fragment operational knowledge.\(^4\)\(^-\)\(^6\)\(^,\)\(^12\)\(^\text{-}\)\(^15\) High levels of efficient automation and computer networks have replaced manual, step-by-step processes in radiation therapy that once allowed a greater degree of tactile practice with multiple opportunities to observe and connect conceptual to applied knowledge in the clinic. Organizational structure and management practices also divide and limit...
knowledge and thereby eliminate learning and teaching opportunities.\textsuperscript{3,6,13} As a result of changes in radiation delivery systems, staff radiation therapists and students are observing, doing, and understanding less. They are less able to connect applied treatment practices to treatment rationales.

Although this argument lacks validity through empirical research, the relevant theories and studies presented provide a level of evidence for its consideration. Clearly, additional research is needed in this area to confirm or disprove this analysis.

\textit{Implications for Policy}

The modern radiation treatment center, as an organizational structure, must confront external pressures to remain competitive and to sustain a rapid rate of technological change. For this reason, learning remains a constant need. This review provides information that organizational decision-makers can use to understand sociotechnical dynamics and to identify possible gaps in workplace learning processes that can affect adoption of new treatment technologies.

For administrators seeking higher levels of organizational effectiveness, a crucial piece of this review to consider is how past knowledge is applied to current practices or how the fragmentation of information or ineffective peer-to-peer learning can hinder seamless transition to new practices.

\textit{Implications for Practice}

Radiation therapists have varying levels of knowledge based on their work history and level of experience. Experienced radiation therapists are able to perceive treatment objectives fully by relying on a deep well of conceptual knowledge while adopting new work practices. Inexperienced radiation therapists must focus directly on learning new tasks at a fast pace as they attempt to “think on their feet,” a situation that makes it more difficult for them to tie conceptual knowledge to their work and maintain their ability for independent clinical judgment.

The adult learning theories examined in this review offer a perspective that lend credence to perceived knowledge gaps among practicing radiation therapists. By viewing all radiation therapists as potential experts and by understanding their need for effective methods of knowledge sharing, workplace learning dynamics may become a focus of future research.

\textbf{Conclusion}

Staff radiation therapists teach entry-level personnel and students by modeling the treatment delivery process. This type of knowledge translation encompasses tacit knowledge. Because learning in the clinical setting focuses primarily on operational knowledge, gaps in conceptual knowledge could develop over generations of radiation therapists. This possibility is underscored by theories of organizational learning, situated learning, systems learning, knowledge management, and sociotechnical systems.

Gaps in conceptual knowledge among staff radiation therapists may be transmitted to students working under their supervision as part of the learning process and may affect the practice of radiation therapy for generations to come.

Future research should test these assertions and, if confirmed, methods of workplace learning should be developed that will ensure optimal radiation therapy practice and patient care.

\textbf{References}


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