AC 2007-89: DESIGNING AN ACTIVITY-BASED CURRICULUM FOR RADIATION PROTECTION PERSONNEL

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Designing an Activity-based Curriculum for Radiation Protection Personnel

Introduction

Recent reports show a need for roughly 90,000 new nuclear employees in the next 10 years. Loss of Radiation Protection personnel (RPs) at nuclear power plants will exceed 57% over the next five years, and over 1,000 replacement radiation protection workers will be needed. This does not include the needs at the US Department of Energy or the impact due to the creation of new jobs from new nuclear power plant construction. Radiation protection personnel serve in numerous facilities that regulate work with radioactive materials in nuclear power plants, Department of Energy facilities, radiopharmaceutical manufacturers, hospitals and research facilities, food irradiation facilities, and university research reactors. Their primary function is to protect other workers from radiation exposure, transport and monitor radioactive materials, and assess exposures to radiation workers.

With the support of a Department of Labor grant, we have designed and will be implementing a certified Associates of Applied Science Degree in Nuclear Technology degree program to contribute toward meeting the energy industry's manpower needs for RPs and to ensure that the demand for qualified, skilled workers is met throughout the U.S. In this paper, we describe our methods for designing the RP curriculum, which began with an extensive needs analysis process. Our needs analysis included an activity analysis, a contextual analysis, and a follow-up task analysis to inform the design of this program. Initial results indicate a need for a curriculum that focuses on task-oriented knowledge acquisition in contexts that support authentic learning.

Needs Analysis

During the initial phase of the project, we performed a needs analysis in order to determine the requirements for the RP academic program. The most common kind of needs analysis for determining curricular requirements identifies the topics or concepts that graduates should know when they have completed the instructional program. More traditional topic-oriented curricula typically result in learning objectives that emphasize recall of concepts. For example, as part of our needs analysis, we analyzed Department of Energy (DOE) and Institute of Nuclear Power Operations' (INPO) RP training objectives. Our analysis showed that, of all learning objectives, 60% focused on memorization, 18% on comprehension of ideas, 18% on application, 3% on analysis, and less then 1% on evaluation of knowledge. Our analysis of the kind of knowledge required by these objectives showed that 52% focused on factual knowledge, 21% on conceptual knowledge, 27% on procedural knowledge, and less than 1% on meta-cognitive knowledge. Our needs analysis also showed that the nuclear industry is probably the most highly regulated in the world, with extensive rules and guidelines provided by the Department of Energy, Nuclear Regulatory Commission, and numerous other task-specific agencies. Given the highly regulated nature of the industry, accountability is essential to these organizations, as well it should be. Too often, accountability is associated with memorization because memorization is the easiest and most reliable form of assessment. However, given the complexity of the tasks that RPs regularly perform and the importance of their performance to the safety of workers potentially exposed to radioactive sources, memorization is insufficient for their preparation. Given the complexity of their tasks and the broad range of contexts in which radiation protection must be provided, the ability to perform numerous problem-solving tasks is essential to job success. Therefore, in order to assess performance needs, we needed a more robust form of analysis for a articulating the curriculum. RPs must be able to readily identify sources of radiation and their interaction with biological and non-biological matter as well as implement methods for mitigating risks to workers, all regulated by a variety of governmental and professional regulations (e.g., NRC, DOE, INPO). Memorization of facts and concepts is insufficient for developing these skills.

Activity Analysis. Therefore, our needs analysis began with the assumption that we must identify what tasks RPs perform. Knowing what they regularly do in different contexts is key to determining what they must know and how they must implement various methods. That is, we needed to analyze the activity systems in which RPs perform RP tasks. The most robust method of analysis for analyzing workplace activity systems is activity analysis[1]. Rather than focusing on knowledge states, activity theory focuses on the activities in which people are engaged, the nature of the tools they use in those activities, the social and contextual relationships among the collaborators in those activities, the goals and intentions of those activities, and the objects or outcomes of those activities. Activity theory creates for the instructional designer a framework to assess tasks within the context in which they occur. Activity theory focuses on the interaction of human activity and consciousness (the human mind as whole) within its relevant environmental context. According to activity theory, the unit of analysis is an activity. The components of any activity are organized into activity systems[2]. RPs regularly perform activities such as assessing potential exposure and establishing safety perimeters around potential radiation sources. Those activities require a number of actions, such as operating a detector to determine exposure or calculating exposure limits. Those actions vary depending on the context in which they are performed (e.g., hospital, nuclear power plant). In those different contexts, the actions are mediated by the use of different tools, regulated by different agencies, or subject to different divisions of labor in the context. By observing and interviewing experienced RPs in different settings, ascertaining the regulatory standards in those contexts, site-specific procedures and documentation, we focused on identifying what RPs do in their jobs. The general process for performing an activity analysis includes (Jonassen et al, 1999):

1. Clarify purpose of activity system within a context.
2. Analyze the subject, the relevant community/communities, and the object of the activity.
3. Analyze the activity structure, including activity and constituent actions and operations.
4. Analyze the tools, rules, and roles that may mediators the activity.
5. Analyze the socio-historical context in which the activity is performed.
6. Analyze the activity system dynamics for contradictions among the components of the system.

In order to perform the activity analysis, we met with RP personnel and health physicists to clarify the purposes of RPs. In addition to monitoring, their job is comprised of risk assessment. Given annual standards for radiation exposure, RPs must estimate exposure and assess risks for radiation workers in the field. We conducted our activity analysis by observing and interviewing RPs and health physicists in nuclear power plants, hospitals, a research reactor, and research centers using radioactive sources. For each of the activities, we analyzed the component skills (actions and operations) involved in completing the activity. For each activity, we identified the roles of the RPs (the subject of the activity system) and the communities in which they work. Those communities vary quite a bit. For instance, a RP in a research center must work with a very different clientele (in terms of background knowledge and skills) than a RP in a power plant. Those workers also manifest different attitudes toward radiation issues, in part because of the inherent radiation risks in their jobs. We also identified the tools they used to perform the activities and the rules that circumscribe performance. The tools involve different detection meters and dosimetry equipment. The rules that describe acceptable processes also vary.

These include Department of Energy regulations, such as 10CFR20, but also Nuclear Regulatory regulations and guidelines from industry associations such as INPO. We also tried to identify the socio-historic differences in the contexts in which RPs operate. In addition to various rules, different radiation contexts also exhibit different cultures, based on the origins and experiences of the workers and the supervisory staff. For example, a great many workers in power plants come from the Navy nuclear program, so they bring a military perspective to their operations. Those socio-historical differences have significant impact on how jobs are perceived and conducted. Finally, we attempted to identify any contradiction that were inherent in the systems, such as contradictions among regulations provided by different agencies, contradictions among the tasks that are performed, or contradictions among the roles that are assumed by different personnel (RPs, health physicists, operators, etc.). The purpose of activity analysis is to articulate the nature of human activities in all of their contextual richness, realizing that the same jobs performed in different contexts may appear and function quite differently. Because the goal of the project is to prepare RPs to work in a variety of contexts, these ecological issues are extremely important in preparing RPs to work in different contexts.

Proposed Radiation Curriculum

Based on our analysis, we identified a set of skills that RPs regularly perform, including performing airborne radioactivity surveys, performing surveys of material and equipment for unconditional release of radioactive sources, monitoring radiation fields, monitoring internal and external exposure of personnel to ionizing radiation, monitoring personnel for internal and external radioactive contamination, inventorying radioactive materials, performing radiological decontamination of areas and equipment, disposing of radioactive high-level and low-level waste materials, maintaining radioactive survey instruments, ensuring radiation detection instrument operability, calibrating radiation survey instruments, identifying and responding to abnormal and emergency radiological conditions, writing procedures to describe tasks, storing radioactive materials, preparing radioactive materials for transportation, providing radiological coverage of jobs and high-risk and low-risk activities (e.g. outages), and responding to emergencies.

Based on these skills, we designed a six-course sequence (see Appendix) that will be implemented at five community colleges (Linn State College, Maricopa Community College, Hill College, Estrella Mountain Community College, Central Virginia Community College). These six courses constitute the radiation protection curriculum for the degree. Additionally, students will be required to complete an additional fifteen to eighteen courses to complete the requirements for the Associate of Science degree.

In addition, students will complete a required internship during the summer between their freshman and sophomore years at a nuclear power plant. Each technical college is partnering with a nearby nuclear power plant in order to provide authentic internship experiences for the students.

Each course in the radiation curriculum represents blended instruction. All curriculum materials will be accessed from a web site. Those materials may be used by instructors in classrooms in a variety of ways from the objects of lectures to problem-based learning. We will provide training and manuals for faculty members on these alternative pedagogies using the materials that we develop.

Each of the six courses that we are developing exhibit the following pedagogical characteristics.

Case-based. Each course is case-based with each case focusing on authentic activities that are regularly performed by RPs in different contexts. Jonassen (2006) articulated five different functions that cases may play in learning environments: cases as exemplars (analogies), cases as remindings (case-based reasoning), case study method, cases as problems to solve (problem-based), and student constructed cases. In these six courses, we provide three different kinds of cases. Each course consists of 12-13 modules. Each module may contain up to three kinds of cases. Students begin studying an exemplar in each module. The exemplar is a worked out case describing an application of radioactive materials or an example of an activity that a RP normally performs. For example, I the radiation monitoring course, students will work through module titled Conduct routine radiation survey of given area according to a given procedure; determine composition of liquid effluent and whether effluent meets requirements for unconditional release, determine radiation levels of solid waste and whether waste meets requirements for release to rad waste facility. The students will study a worked out cases. While studying these cases, students will also be exposed to cases as remindings in the form of INPO event reports. Finally, students will solve a transfer case that is a problem to solve. The case will be structurally similar to the exemplar I a different context. Students will be required to conduct the analysis, determine the procedures, and perform all of the calculation needed to solve the radiation protection problem

Analogical Transfer. After studying the exemplar case in each module, students will be required to transfer what they have learned from that case to another case that is not worked out. The transfer case will comprise a problem to solve. The case will be structurally similar to the exemplar but in a different context. Students will be required to conduct the analysis, determine the procedures, and perform all of the calculation needed to solve the radiation protection problem. Analogical transfer requires that analogues be structurally similar rather than contextually similar in order to support generalization across a variety of contexts.

Narrative Format. Each of the cases is presented in a narrative format. Narrative representations are better understood and far better remembered than expository representations. Stories are the oldest and most natural form of sense making. Stories are the "means [by] which human beings give meaning to their experience of temporality and personal action[4]. Humans appear to have an innate ability and predisposition to organize and represent their experiences in the form of stories. Stories helps us to learn, to conserve memory, or to alter the past [5] and allows us to embark on the authentic exploration of experience from a particular perspective

Ask System. In order to help students to analyze radiation processes, we developed a set of model questions that RPs should ask whenever they face a new radiation protection situation. Those questions are modeled for students in the web-based environments in the form of an Ask System. The Ask System is found on the left side of the screen. It consists of questions that learners may ask about an authentic work task that is presented to the learners in the form of a story-based scenario. Learners ascertain the scope and execution of the problem by selecting from a constrained set of questions provided by the system (Fig. 1). Knowledge is not constructed by the system or based on theoretical domain representations; rather, the learner actively constructs knowledge by interfacing with the system, thus affording a learner-centric mode of knowledge acquisition within authentic contexts of real-world scenarios[6,7]. The Ask System enables learners to access expert answers to questions much the same way as they would in the context of completing a real task, that is, by asking questions [7,8]. At a basal level, an Ask System attempts to emulate a conversation with an expert (Bareiss & Osgood, 1993). This conversation is conducted between learners and the system by means of Aesopic dialogues, that is, dialogues in which the learner selects from a constrained set of questions within the system, and the system responds with pertinent answers, mostly in the form of stories [3]. Answers are gleaned from extensive interviews with expert practitioners and indexed based on an explicit task-model, and are presented in the form of 30 second to two-minute long video and/or audio clips, as well as in plain text. The content of these answers along with the Ask System's point-and-click interface are what imbue the system's functionality [3]. In essence, we believe our Ask System facilitates access to expert knowledge, provides for a learner-centric mode

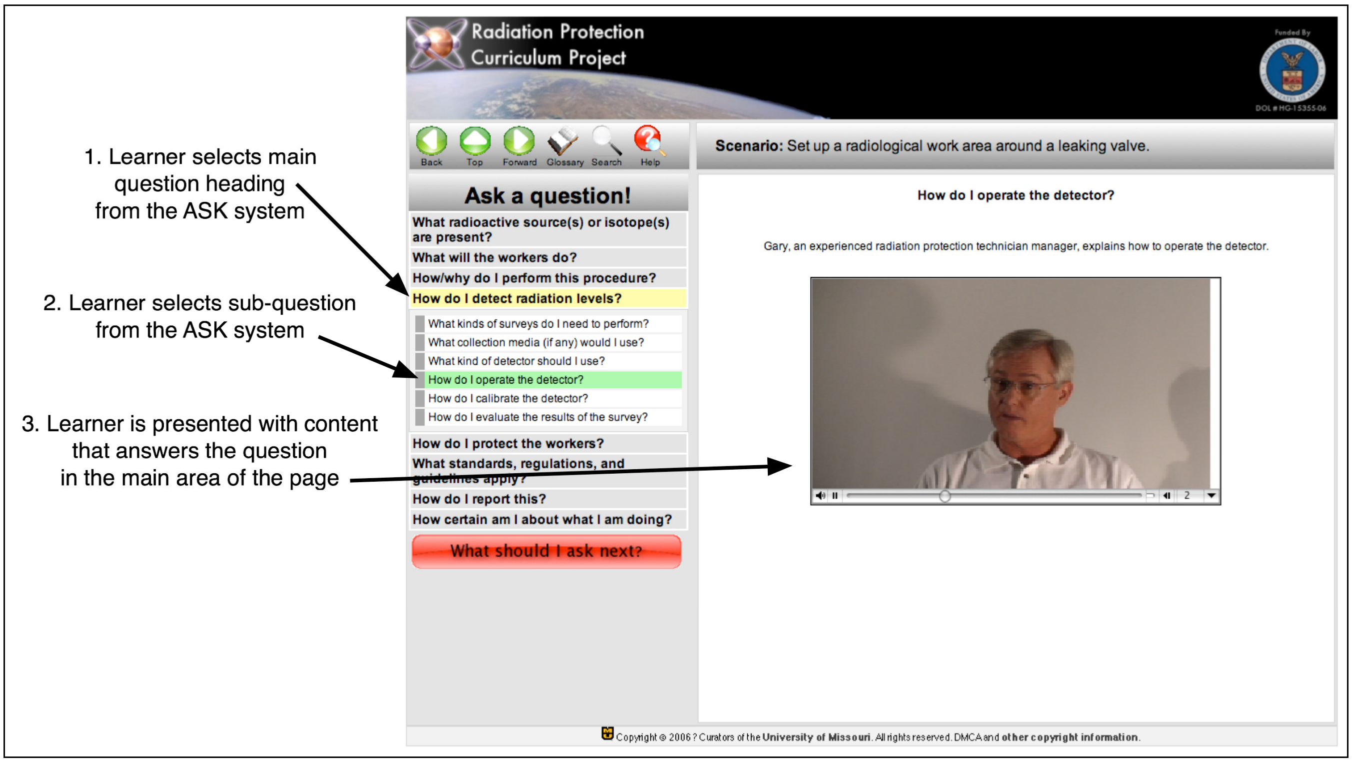

Figure 1.

of learning, and grounds that learning in the contexts of domain- and task-specific knowledge. We conducted formative evaluation of the Ask System with students enrolled in the RP program at one of the community colleges. Data were collected on conceptual problems and preferences, and changes were made according to that evaluation.

The questions that are used to structure most of the courses include the following general questions. When learners click on the general question, they are presented with the more specific (indented) questions. When any of those more specific questions are selected, the answer to the question, along with some explanation, is presented.

- What radioactive source(s) are present?
    - What isotope(s) are present?
    - What type of radiation is emitted (alpha, beat, gamma, positron)?
    - What is the half life of the each isotope?
    - What is the atomic structure of each of the isotope?
    - What are the usual symbols each of the isotopes is denominated by?

    - What are the energy levels?
    - What is the isotope(s) decay process?
    - How does the isotope(s) interact with matter?
    - What impact would each isotope have on the environment?
    - Why/where is that source(s) used?
    - What is the exposure or dose?
- How do I calculate changes in energy levels?
    - How do I convert exposure to dose equivalence?
    - What is the formula?
- How do I perform this procedure?
    - How does a RP Technician describe this?
    - How does another RP Technician describe this?
    - What lessons would a health physicist provide about this activity?
    - What would a nuclear scientist say about this activity?
    - How do I describe this procedure?
    - Are there event reports that are similar?
- How certain am I about what I am doing?
    - How do I self-monitor this activity?
    - Whom should I ask to validate what I am doing?
    - What questions would I need to ask the workers to better assess the situation?
    - Should I check my actions/calculations with someone else?
    - What problems should I anticipate?
    - How much time will this activity take?
    - How should I budget time for this activity?
- What regulations/standards apply to this activity?
    - What DOE regulations apply?
    - What NRC regulations apply?
- What guidelines apply to this activity?
    - What INPO regulations apply?
    - What ACAD guidelines apply?
- How would you report the results of this activity?
    - What records must be kept?

It was necessary to adapt the ask System for different courses in order to highlight questions that are relevant to those scenarios. For example, for the Radiation Monitoring course, the following questions are added.

- How do I detect radiation levels?
    - What kinds of radioactive surveys do I need to perform?
    - What collection media (if any) would I use?
    - Which kind of detector should I use (gas-filled, Germanium, scintillation, ionization chamber)?
    - How do I operate this device?
    - How do I calibrate this device?
    - How do I evaluate the results of the survey?
- How should I protect workers in this situation?

- What are the radiation fields and stay times for workers?
    - What protective clothing is necessary?
    - What kind of equipment should be used (glove box, hot box)?
    - What kind of shielding should be used (Plexiglas, lead)? Where should it be placed?
    - What signs should be posted?

For the Radiation Dosimetry course, the following questions are added to he Ask System.

- How do I measure external/internal dosages to humans?
    - What question do I need to ask to assess the situation?
    - What kind of dosimeter(s) should be used?
    - How do I operate this instrument(s)?
    - How do I evaluate the results of the detection instrument(s)?
- What do I do for exposed workers?
    - Based on the measurements/calculations, what are the possible biological effects on the workers?
    - How would you diagnose these biological effects?
    - How would you perform radiological decontamination of the workers?
    - Is bioassay needed to determine the contamination level to the worker, and if so, what type of bioassay is most appropriate?

Implementation and Evaluation

The first two courses, Radiation Fundamentals and Radiation Monitoring, will be implemented in the five community colleges during the Fall 2007 semester. The remaining courses will be implemented in the colleges during the Fall 2008 semester. Thereafter, they will be offered on a rotating basis at each of the community colleges. Beginning in the fall 2007, we will conduct summative evaluation on the learning environments.

During the summer, 2007, faculty members who are hired to teach in these programs will attend training sessions design to enable them to implement and support this new curriculum. Faculty members will also be supported by a Teaching Guide that will contain suggested teaching methods, references to additional materials, and sample assessment items.

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Radiation Fundamentals (modules)

1. Naturally occurring/background radiation
2. Radiography
3. Therapeutic Medicine
4. Gauging
5. Diagnostic Imaging
6. Purposeful Modification by Radiation
7. Nuclear Analysis Techniques
8. Reactor Theory
9. Pressurized Water Reactors (PWRs)
10. Boiling Water Reactors (BWRs)
11. Accelerators

Radiological Monitoring

Perform airborne radioactivity surveys
Perform surveys of material and equipment for unconditional release of radiological controls
    Monitor radiation fields, Ionizing and Non-Ionizing
    Specify appropriateness of methods based on radionuclides and general
        workplace characteristics and operations
Properly use instruments to evaluate hazards based on radiation type, source characteristics, required sensitivity, and accuracy and precision
Perform analyses to determine characteristics of radioactive material
    Select appropriate environmental radiological detection instrument
    Operate radiological detection and survey instruments
        Operate Geiger counters, scintillations counters, etc.
        Operate continuous air monitors to quantify airborne radioactive material
        Operate HEPA vacuum and ventilation equipment
            External Radiation Levels
            Surface Contamination
        Frisking and scanning techniques
        Testing of exhaust hoods, air flow paths, and exhaust filters
        Use of collection media for tritium, radioiodine, particulates
Interpret and report results
    Account for ingrowth of decay products, decay of radionuclides, activation and radioactive decay chains, in all facets of radiation protection
    Evaluate background counting data to determine proper operation of radiation measurement systems
    Evaluate of radiation fields and stay-times from survey measurements
    Evaluate interferences
    Evaluate sample results including lower limit of detection, decision level, Type I and Type II measurement errors
Perform air, solid and liquid radiation and radioactive contamination surveys
    Evaluate effluents in terms of regulatory compliance
    Identify source of effluent (cladding, coolant leakage)
    Check sealed source leaks

Write procedures to describe tasks
Post and depost radiological areas
Monitor for non-radioactive hazardous environments typically associated with confined spaces and confined space entry programs.
Remote monitor environment
Write procedures to describe tasks
Brief others on incident
Environmental monitoring

Radiation Dosimetry
Monitor internal and external exposure of personnel to ionizing radiation
Monitor personnel for internal and external radioactive contamination
Select and survey appropriate external monitoring devices (dosimeters)
Predict biological effects of radiation
Select appropriate radiological dosage detection instrument
Operate radiological dosage detection instruments
Whole body counts
Annual reviews
Optical dosimetry
Interpret and report results
Evaluate whole body and organ dose from dosimetry results
Conduct internal dosimetry
Determine if bioassay needed
Choose form of bioassay
Predict biological effects
Schedule or administer bioassay
Determine if dose limits exceeded
Administer controls to prevent or minimize environmental and personnel internal and external radiation exposure and contamination
Perform radiological decontamination of personnel
Diagnose health effects of contamination
Write procedures to describe tasks

Radioactive Materials Handling
Inventory Radioactive materials as required
Perform radiological decontamination of areas and equipment
Dispose of radioactive high-level and low-level waste materials
Identify sources and levels
Select disposal or mitigation methods
Develop plan and compare plan with regulations)
Ensure waster permits are up to date
Properly dispose sources of solid waste (spent reactor fuel, de-ionization resins, filters, evaporators, protective clothing, glassware, tools, contamination control materials)
Identify amounts of and properly dispose of sources of liquid waste (reactor

coolant, cooling water, solvents, pumps oil, chemical reagents, scintillation fluids) – evaporate, dilute, ion exchange, decay

Identify sources of amounts of and air-born waste (fission product gases, neutron activation of coolant) – filter, decay, chemical

Provide radioactive waste disposal options (sorting materials; volume reduction techniques; release of clean trash from RCA; liquid waste processing; store waste temporarily on-site)

Dispose of radioactive waste

Decontaminate tools and equipment

Write procedures to describe tasks

Dispose of non-radioactive, hazardous waste

Radiological Safety and Response

Maintain radioactive survey instruments

Ensure radiation detection instrument operability (troubleshooting)

Calibrate radiation survey instruments

Maintain emergency readiness status

Identify and respond to abnormal and emergency radiological conditions

Identify adverse trends in radiological conditions

Respond to radiological alarms

Perform actions to mitigate the consequences of abnormal and emergency radiological conditions

Coolant losses

Fuel-handling accidents

Steam tube ruptures, waste gas tank ruptures)

Facility Emergency Operations

Decontaminate site

Set up security area

Write procedures to describe tasks

Store radioactive materials

Prepare radioactive materials for storage

Select appropriate storage devices and media

Monitor stored radioactive materials

Survey materials on a regular basis

Prepare radioactive materials for Transportation according to DOT regulations

Provide safe control, movement, use, and storage of radioactive materials on owner controlled property

Radiation Protection

Provide radiological coverage of jobs and high-risk and low-risk activities (e.g. outages)

Planning for radiological protection

Assess activities for radiological concerns and provide technical assistance and guidance to personnel planning activities in radiological areas to maintain radiological exposure ALARA

Determine required internal protection (respirators, hoods, glove boxes, hot boxes, protective clothing

Determine necessary shielding

- Conduct job/project specific surveys
- Issue permits and post work areas
- Brief, debrief, and coach personnel performing activities in radiological controlled areas, including their entrance and exit
- Review internal projects for license and application congruence
- Establish administrative dose control levels

Monitor activities in radioactive zones

- Exercise stop-work authority to prevent or mitigate radiological hazards
- Direct and instruct personnel in the performance of radiological control activities
- Document radiological activities and conditions

Respond to Emergencies

Write procedures to describe tasks