Creating and Evaluating an Interactive, Web-Based Module for the Instruction of Radiation Therapy Simulation

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Abstract

Maintaining effective educational strategies in rapidly advancing fields like radiologic sciences is a challenge for educators. This study evaluates the effectiveness of an instructional module for radiation therapy patient simulation. A pre/post-test quasi-experimental design was utilized for the study; six radiation therapy programs from the following states participated: Illinois, Minnesota, Nebraska, Pennsylvania, and Virginia. The subjects for this study consisted of 67 first- and second-year radiation therapy students. Results indicate an increase in scores from pre- to post-test after completion of the module as well as positive student feedback in regard to their perceptions on the effectiveness of the module. An interactive web-based educational module can be used effectively to teach radiation therapy students about the simulation process.

The delivery of radiation therapy is comprised of a variety of activities: treatment planning, simulation, treatment delivery, quality control, and patient visits with health care providers. Treatment planning for radiation therapy begins with the simulation. Simulation, conducted by the radiation therapist under the supervision of a radiation oncologist, mimics the actual radiation therapy procedure with radiographic documentation of the treatment area (Washington & Leaver, 2010). The primary purpose of simulation is to assist in the establishment and documentation of the appropriate treatment volume and identification of the normal structures within and/or adjacent to this volume (Washington & Leaver, 2010). The process of simulation has played an integral part in radiation therapy treatment planning for many years. As technology has evolved, so has the simulation process. There are two main approaches to the simulation process: conventional simulation and computed tomography (CT) simulation.

Conventional simulators combine the components of a diagnostic x-ray machine with the components of a radiation therapy linear accelerator to mimic the functions of the treatment machine. The conventional simulation process utilizes both flouroscopy and conventional radiographs to delineate the treatment field primarily through the use of bony landmarks.

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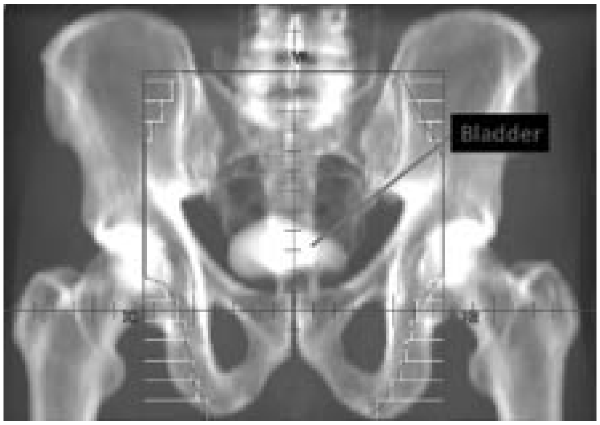

Figure 1. Conventional Simulation Image – Pelvis

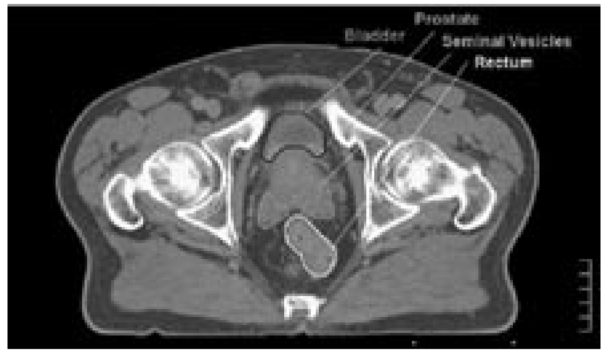

Figure 2. Computed Tomography Simulation Image – Pelvis

Figure 1 shows an AP radiograph of the male pelvis obtained during conventional simulation of the prostate. Note that the prostate cannot be visualized on this radiograph. The radiation oncologist must rely on the use of bony landmarks within the pelvis and the contrast-filled bladder to establish the treatment area for the prostate.

In the 1970s, CT was introduced to the simulation process, although the first commercial CT simulators did not become available until the mid-1990s (Baker, 2006; Mutic, 2001; Zimeras, 2001). CT simulators provide a three-dimensional representation of patient data thus allowing the radiation therapy team to better localize not only tumor volumes, but their relationship with surrounding normal anatomy (Baker, 2006). Figure 2 shows an axial CT image of the male pelvis obtained during CT simulation of the prostate. Note the ability to visualize not only the treatment volume (prostate and seminal vesicles), but also the surrounding normal anatomy (bladder, rectum, and bony pelvis). The data obtained through the use of CT simulators allows the process of patient scanning, tumor and target localization, treatment planning, and treatment field verification to be fused into one integrated operation (Mutic, Purdy, Michalski & Perez, 2010).

Currently the standard of care in radiation therapy departments is conformal therapy planned through the use of CT simulation. Conformal therapy is a treatment technique that utilizes 3D images obtained during CT simulation to plan patient treatment using multiple beams. These multiple beams conform to the tumor volume (Washington & Leaver, 2010). The process of treatment planning for conformal therapy is often referred to as virtual planning because the planning process uses volumetric images of the patient rather than actual patient measurements obtained by the radiation therapist (Washington & Leaver, 2010). With increased used of virtual planning, the opportunity for radiation therapy students to experience conventional simulation is decreasing every year. Although clinical competency in conventional simulation may soon become irrelevant, the ability to understand the importance of the parameters determined during the virtual simulation process and how radiation affects the patient through these planned parameters is essential (Washington & Leaver, 2010).

The purpose of this study was to develop and evaluate an online educational module to provide students with a thorough understanding of how and why treatment parameters are established in relation to simulation and instruction on therapy parameters such as field delineation, volume localization, and dose distribution. The online educational module serves as a supplement to the current curriculum focusing on different aspects of the simulation including treatment field delineation, immobilization, measuring and marking of the patient, treatment volume and tumor localization, and isocenter determination. We hypothesize that radiation therapy students who complete the online educational module will achieve higher scores on the post-test than they achieved on the pre-test.

Literature Review

Teaching and Learning in Medical Education

Gross (1993) notes learning to be an "active, constructive process that is contextual: new knowledge is acquired in relation to previous knowledge; information becomes meaningful when it is presented in some type of framework" (p. 177). Students approach learning and the acquisition and understanding of knowledge in different ways. Learning styles help to define how individual students learn.

Teaching in medical education involves the unique aspects of both didactic and clinical teaching. Pitman (1983) noted the importance of learning styles in the education of health occupations students; information on learning styles can help by providing better educational experiences. Instructors who teach based on student learning styles make the shift from the traditional teacher centered approach to more of a student-centered approach. Spencer and Jordan (1999) state that "the pedagogic shift from the traditional teacher center approach to a student centered approach requires a fundamental change in the role of the educator from that of a didactic teacher to that of a facilitator in learning" (p.1).

Laidlaw and Hesketh (2005) suggest a blended learning approach to teaching in medical education. Blended learning can enhance face-to-face teaching by adding an instructional model that allows instruction and learning to occur independent of place and time (Saltxberg & Polyson, 1995). When used in medical education, blended learning supports clinical teaching with online course materials, pre-reading materials, study guides, mentorship, discussion boards and formative assessment (Laidlaw & Hesketh, 2005). Possible benefits of a blended learning method include increased quality of evidence-based teaching and learning, cost effectiveness, and better time management for both clinicians and students (Laidlaw & Hesketh, 2005).

Instructional Technology in Radiologic Education

Instructional technology involves the use of multimedia and technology to enhance the learning experience. Multimedia may come in the form of text, graphics, animations, audio, or video. When presented through the use of a computer, multimedia provides the learner with the opportunity to navigate, interact, create, and communicate (Hofstetter, 1995). The use of instructional technology and multimedia can be especially useful in radiologic education due to the fact that the field of radiology involves the use of highly visual content (Grunewald, Heckerman, Gebhard, Lell & Bautz, 2003). According to Jaffe and Lynch (1995), repeated visual experiences are more effective in promoting learning in radiologic education than verbal descriptions alone.

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Harris (2002) reviewed a number of studies on the effectiveness of multimedia-based instruction. Instruction via multimedia "creates an active learning environment, improves student performance, fosters positive attitudes toward learning complex concepts, increases communication and can be adapted to all learning styles and levels of instruction" (p. 839).

When paired with online education, instructional technology not only provides learners with the ability to access instruction at virtually any time or any place, it also allows instructors to build more interaction into the educational experience (Grunewald et al., 2003; Gunderman, Kang, Fraley & Williamson, 2001). Jaffe and Lynch (1995) note that effective online education expresses a philosophy of teaching and includes the use of instructional technology that is "engaging, spontaneous and rich in images and dynamics" (p. 467). Course design is an important facet of effective online education.

Online Education and Interactivity

Numerous factors must be considered when planning and organizing for online education, with interaction considered one of the most important. Jonassen (1988) noted that "computer-based instruction provides greater potential for truly interactive instruction than any mediated teaching device to date, excluding in many instances, the human tutor" (in Sims, 2003).

Moore and Kearsley (2005) identified three basic types of interaction that help facilitate effective online education: learner-content interaction, learner-instructor interaction, and learner-learner interaction. When developing online education, the interactivity between the learners and the technology delivering the content must be taken into consideration. Whether the content comes in the form of audio, video, text, or graphic representations, the instructor must support and assist the student as he or she interacts with the content. Moore and Kearsley (2005) note learner-to-content interaction to be the defining characteristic of education.

According to Simonson et al. (2009), to teach and learn effectively in an online environment, instructors must also strive to incorporate the concepts of stu-

Table 1. Pre-Module Survey Data

Pre-Module Questions & Responses					
1. In terms of the radiation therapy program in which you are currently enrolled, which of the following best describes your progress in the program:	I have just started a 1 year – 18 month program (enrolled 3 months or less). (3.39%, n=2)	I am halfway through a 1 year – 18 month program (enrolled in the program for at least 6 months). (20.34%, n=12)	I have almost completed a 1 year – 18 month program (less than 3 months until graduation). (38.98%, n=23)	I am a first year student in a 22-24 month program. (5.09%, n=3)	I am a second year student in a 22 - 24 month program. (32.20%, n=19)
2. In terms of your experience with Computed Tomography (CT) simulation, which of the following best describes the amount of exposure you have had to CT simulation alone:	I have only had classroom training on CT simulation. (3.39%, n=2)	I have had classroom training and some clinical training on CT simulation. (37.29%, n=22)	I have had classroom training and some clinical training on CT simulation, which has enabled me to complete several required competencies on the CT simulator. (45.76%, n=27)	I have had extensive classroom training and clinical training on CT simulation. I feel competent in simulating patients utilizing CT. (10.17%, n=6)	I have had no training on CT simulation. (3.39%, n=2)
3. In terms of your experience with conventional (fluoroscopy-based) simulation, which of the following best describes the amount of exposure you have had to conventional simulation alone:	I have only had classroom training on conventional simulation. (8.47%, n=5)	I have had classroom training and some clinical training on conventional simulation. (44.07%, n=26)	I have had classroom training and some clinical training on conventional simulation, which has enabled me to complete several required competencies on the conventional simulator. (33.90%. n=20)	I have had extensive classroom training and clinical training on conventional simulation. I feel competent in simulating patients utilizing the conventional simulator. (6.78%, n=4)	I have had no training on conventional simulation. (6.78%, n=4)
4. In terms of clinical competencies for simulation required for graduation, which of the following best describes your progress to date:	I have not yet completed any of the required competencies for simulation. (8.47%, n=5)	I have completed less than half of the required clinical competencies for simulation. (22.04%, n=13)	I have completed over half of the required clinical competencies for simulation. (61.02%, n=36)	I have completed all of the required clinical competencies for simulation. (8.47%, n=5)	
5. Which of the following best describes your background in radiology?	I completed a radiograph program before entering radiation therapy school. (61.02%, n=36)	I completed a nuclear medicine program or other radiation science modality before entering radiation therapy school. (0%)	I did not complete a radiography program or other radiation science modality before entering radiation therapy school. (38.98%, n=23)		

dent-centered learning. Student-centered learning, also referred to as active learning, encourages students to take responsibility for their learning and to become more actively involved in the learning process (Watherhouse, 2005). Within a student-centered online learning environment, students become engaged in activities that encourage both student-to-student and student-to-content interaction (Moore & Kearsley, 2005; Waterhouse, 2005).

Online Education in Radiologic and Allied Health Sciences

Extensive research has been done in regard to the effectiveness of on-line learning. Unfortunately, little of this research pertains specifically to education in radiation therapy or the field of radiologic science. Simonson et al. (2009) cite that distance education can be successful as evidenced by the fact that students of all ages can learn from instruction delivered using technology.

Johnston (2008) compared the instructional effectiveness of two radiologic science courses, patient care and radiation biology and protection. Although specifics in course design were not included, both courses were initially taught using a face-to-face format and converted to an online format. The results of the study were somewhat mixed. A slight increase was noted in the overall grades for the on-line group versus the face-to-face instruction group, however; long-term retention seemed to be an issue as student board exam scores did not reflect this increase (Johnston, 2008).

Research conducted in regard to distance education in the field of radiologic science education often falls under the broader topic of distance education in allied health science education. Williams (2006) conducted a comprehensive meta-analysis of research-based distance education literature for allied health science education with emphasis on the design components of effective online instruction. The effectiveness of three distance-education learning models was studied: a distributed classroom (synchronous learning in which students receive instruction at a set time and a set place off-campus), an independent classroom (asynchronous learning in which students complete course content anytime and anyplace) and an open classroom (both synchronous and asynchronous learning) (Williams, 2006). Based on the study, the most effective model of distance education for allied health students was synchronous and open learning (Williams, 2006). Another important finding in the study was the fact that more interactivity in a distance education course had positive effects on student achievement levels (Williams, 2006).

Methodology

This study examines the effectiveness of an online educational module based on radiation therapy simulation. We hypothesize that radiation therapy students who complete the educational module will achieve higher scores on the post-test than they achieved on the pre-test. To address the question, researchers used a pre-test/post-test quasi-experimental design with an intact group of radiation therapy students. An experimental design is used when a researcher wants to test a treatment or an idea to determine whether it has an influence on the outcome or the dependent variable (Creswell, 2008, p. 299). A pre-test provides a measure of a particular attribute before the treatment is administered and the post-test provides a measure of the same attribute after the treatment (Creswell, 2008).

Subjects

Six radiation therapy programs throughout the United States were selected to participate in the study. The programs participating voluntarily included programs in Illinois, Minnesota, Nebraska, Pennsylvania, and Virginia. The programs ranged from 12 to 24 months in length. Radiation therapy students participating in the study were required to be in good standing within their educational program. Both first- and second-year radiation therapy students participated in the educational module as part of their required curriculum. A total of 67 students participated. Forty-seven of the students were female and 20 of the students were male.

Due to the fact that both first- and second-year students were allowed to participate in the study, all students were asked to complete a pre-module survey (Table 1). The survey was used to gain information about the current educational level of the participating students in regard to the simulation process. Fifty-nine students completed the survey. Results of the survey demonstrate that 5 of the students were in the beginning months of their program while 54 of the students had been enrolled for 6 months or more.

Procedure

This study was approved by the Institutional Review Board at the University of Nebraska Medical Center.

Table 2. Sample of Pre/Post-Test Questions (correct answers are in bold).

1) Patient separation refers to the measurement of the thickness of a patient along the central axis.
a. True
b. False

2) When treating the pelvis with radiation, the most dose limiting structure is the:
a. Kidney
b. Bladder
c. Small bowel
d. Rectum

3) Where is the prostate located in relation to the rectum & bladder?
a. Anterior to the rectum & superior to the bladder
b. Anterior to the rectum & inferior to the bladder
c. Posterior to the rectum & superior to the bladder
d. Posterior to the rectum & inferior to the bladder

4) Which of the following is NOT an advantage of CT simulation compared to conventional simulation?
a. Decreased patient dose due to a reduction in simulation time
b. Increased patient compliance due to reduced simulation time
c. Ability to acquire 3D data leading to better visualization of tumor volume and nodal involvement
d. Ability to improve dose delivery to target volumes and reduce dose to critical organs through the use of CT slices in treatment planning

5) Which of the following best describes, in order, the sequence of events that should occur during conventional simulation of the prostate?
1. Localization of the isocenter and delineation of the treatment parameters through the use of fluoroscopy
2. Immobilization and alignment of the patient
3. Definition of the field on the simulation film by the radiation oncologist
4. Measurement of patient separation and definition of isocenter on the patient's skin
5. General reference point defined by the therapist through the use of bony landmarks
6. Verification of SSD's and completion of radiographic images for involved treatment fields.
a. 5, 2, 1, 3, 4, 6
b. 2, 5, 1, 4, 6, 3
c. 1, 2, 5, 6, 3, 4
d. 2, 6, 5, 1, 4, 3

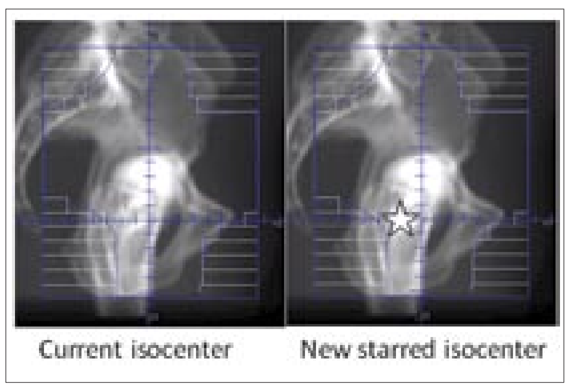
6) During localization of the target volume of the prostate, ___________ is often used to locate the bladder & the urethra.
a. Air
b. Barium
c. Iodine contrast media
d. Radium

7) Prostate carcinoma originates most often in the peripheral portion of the gland.
a. True
b. False

8) The degree of rectal and bladder filling does not affect the position of the prostate.
a. True
b. False

9) The inferior border of a prostate field is determined by the inferior most aspect of the prostate, which will vary for each individual patient.
a. True
b. False

10) The radiation oncologist decides that the isocenter for the lateral prostate field needs to be 1 cm posterior to the current isocenter (see pictures below). What adjustments would you make to the table height and the patient SSD to change the isocenter?
a. Raise the table changing the SSD from 86 cm to 85 cm
b. Raise the table changing the SSD from 86 cm to 87 cm
c. Lower the table changing the SSD from 86 cm to 85 cm
d. Lower the table changing the SSD from 86 to 87 cm



The study used a pre-test/post-test quasi-experimental design. Radiation therapy students completed a pre-test and a post-test with an intervening educational module designed to improve their knowledge of the simulation process (see Table 2). The students also completed a short post-module evaluation on their perceptions of the educational module. Each student completed the module independently, in a proctored setting within a 2-to-3 hour time span. The students could access the radiation therapy simulation module via the Internet. The module resided on an institution-supported Blackboard course management system.

The Instructional Module

The radiation therapy simulation module was created to supplement the current curriculum for radiation therapy students with the addition of an online, multimedia-based educational tool. Persons involved in the creation and/or review of the educational module included the radiation therapy program director, the radiation therapy clinical coordinator, and radiation therapy faculty. An online learning format was chosen versus a traditional face-to-face setting to allow accessibility for students completing the module from a distance. Based on the findings in the literature, the radiation therapy faculty strived to create an online educational module that focused on interactivity and student-centered learning. A blended learning approach was utilized as the module will serve as a supplement to the current didactic and clinical teaching curriculum.

The educational module was housed on an institution-supported Blackboard course management system. Course management systems or web-based learning systems enable instructors to create and organize resources through online software packages (Waterhouse, 2005). Course management systems provide resources that allow instructors to manage course content, author content, create online assignments, foster collaboration through both asynchronous and synchronous communication, and create online examinations.

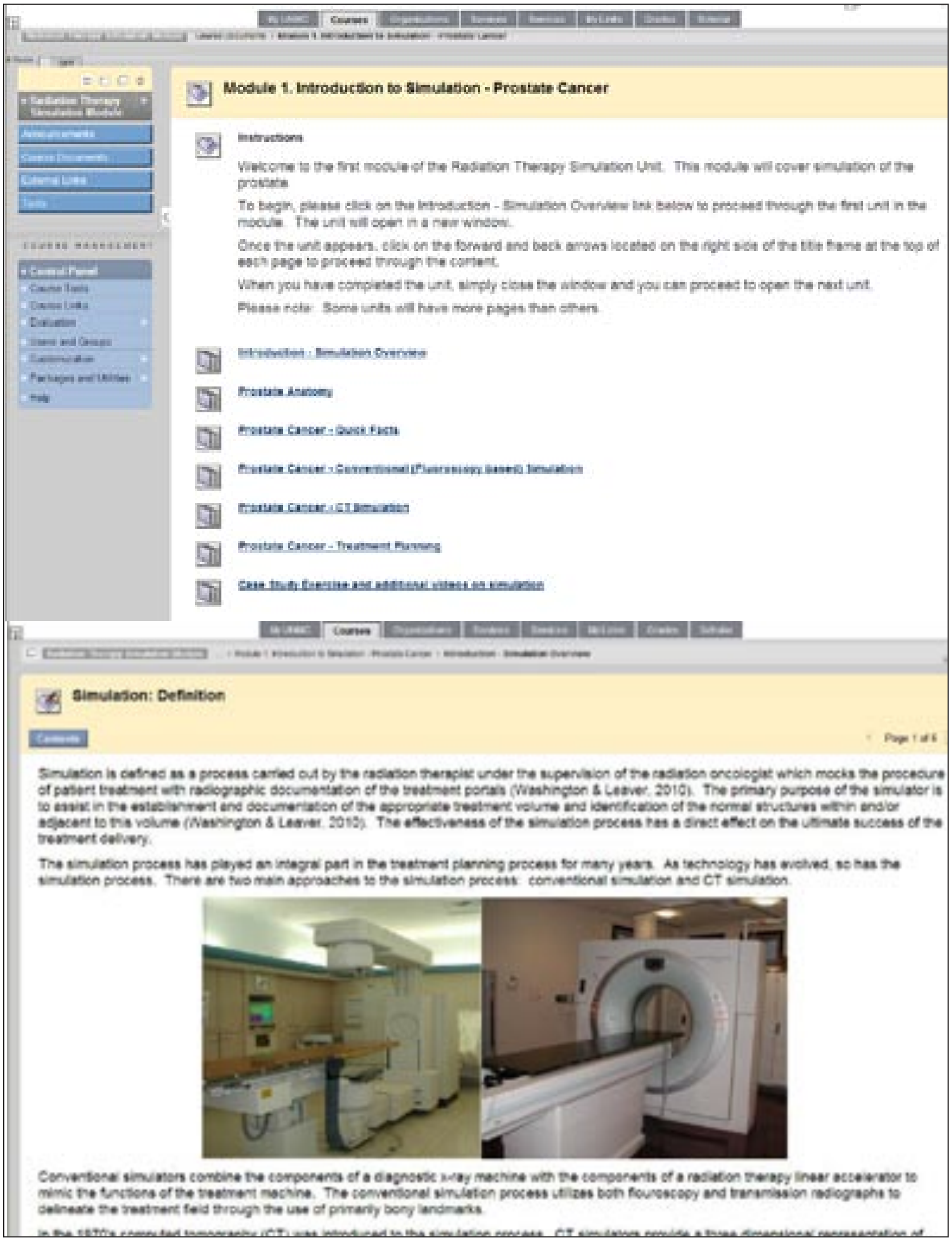
The educational module implemented for this research study was based on the simulation process for prostate cancer (Figure 3, page 26). In developing the module, the goal was to create an interactive, student-centered learning environment. Based on the information from the pre-module survey, over 75% of the students completing the module stated that they were currently in the latter half of their program and had experienced didactic training based on the simulation process. Based on this information, the instructors began the module with a simple overview including graphics, short YouTube videos (http://www.youtube.com/watch?v=DFXCrhmhG5s) and PowerPoint presentations. Basic information regarding the simulation process, prostate anatomy, and prostate cancer were covered to build upon the student's prior knowledge. This section of the module also included an interactive quiz created with Hot Potatoes software (http://hotpot.uvic.ca/) based on the information presented. The students received immediate feedback throughout the 10-question quiz. The module developers hoped to reinforce students' learning from their responses by including both positive and negative feedback.

A detailed overview of the processes of conventional simulation and CT simulation was covered in the next section of the module (see Figure 4 and 5, pages 27, 28). Informational PowerPoint presentations followed by narrated videos of both a conventional simulation and a CT simulation of a patient diagnosed with prostate cancer were included. The videos were created specifically for the module within the radiation therapy clinical setting and portray step-by-step illustrations of the simulation process. Moore and Kearsley (2005) note video to be a good medium for teaching procedural information via distance due to the ability to show the sequence of actions involved. Attributes and benefits of using video include the capability of showing close-ups, slow or accelerated motion and multiple perspectives (Moore & Kearsley, 2005).

As mentioned previously, the use of conventional simulation is decreasing and in some cases has become non-existent in many radiation therapy departments. While the importance of capturing a process that is becoming extinct may seem irrelevant, there are obvious benefits for the radiation therapy student. Students are expected to have knowledge of certain aspects of conventional simulation for their board exams, not to mention the benefit for those who may go on to work at smaller rural facilities that utilize only conventional simulation.

The final section of the module addressed information regarding the treatment planning process. The information presented compared forward treatment planning utilized with conventional simulation and virtual or inverse planning utilized with CT simulation. This unit included text, graphics, and PowerPoint presentations. The unit concluded with an interactive prostate case-study exercise developed through the

Figure 3. Example of Module 1—Prostate Cancer: Introduction to Simulation



use of Quandry web-based software (http://www.halfbakedsoftware.com/quandary.php). The interactive case study presented students with a situation related to prostate cancer and simulation. The students were then given a number of possible solutions. Students worked through the case study like a branching tree; as they chose one option, a resulting situation was presented with another set of options. Working through the case study provided the students with a problem-based learning exercise in which they could apply the knowledge they had learned, engage in critical thinking and work on practical real-world situations.

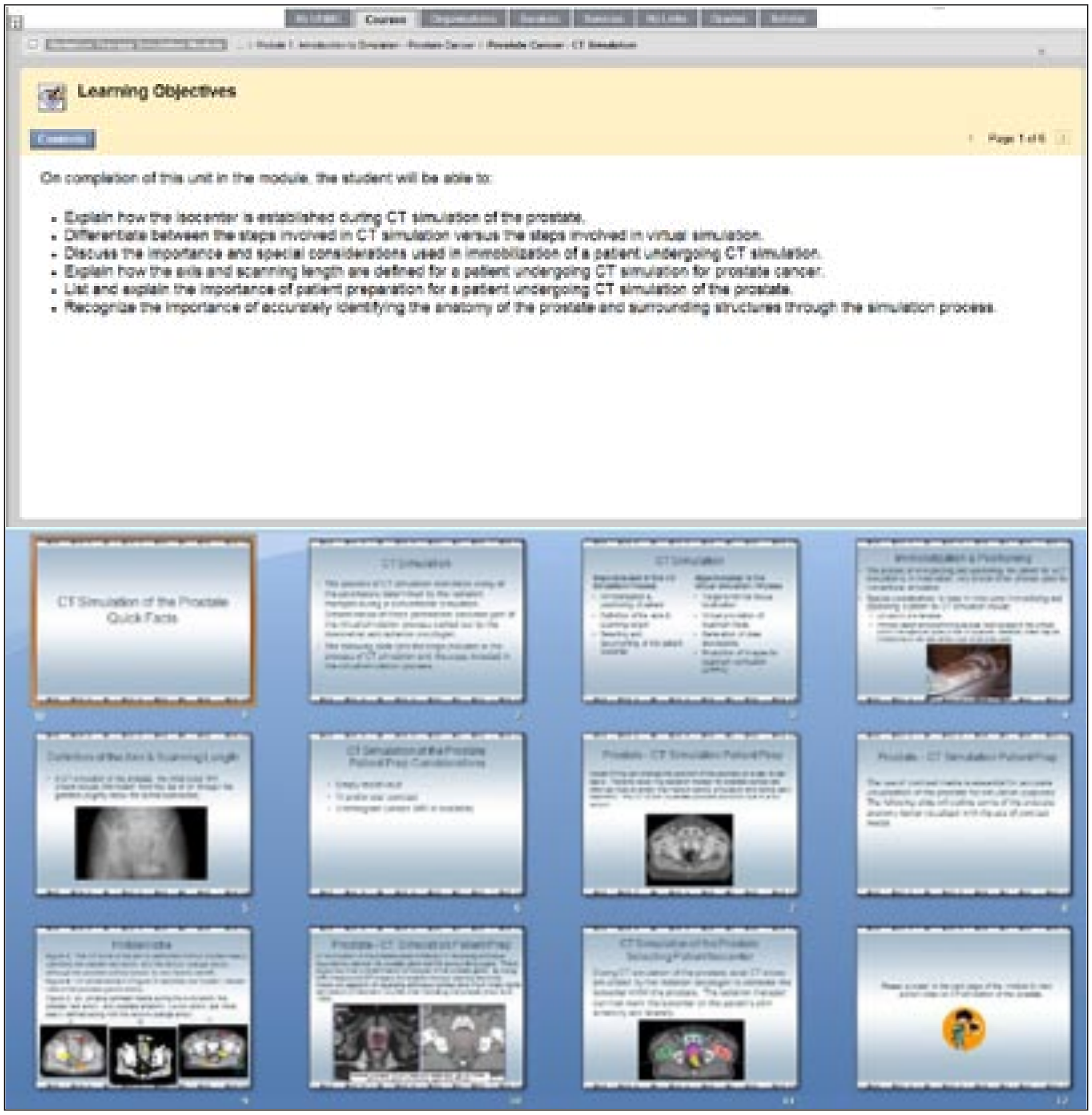
Figure 4. Example of Module for Prostate Cancer—Conventional Simulation

In addition to the educational content, the module included an identical pre- and post-test consisting of 10 multiple choice and true/false questions. The questions were developed and edited by the radiation therapy faculty and focused on knowledge, comprehension, and application skills. Although the educational module included a review of prostate anatomy and a prostate cancer overview, content selected for testing purposes was based solely on the objectives written for conventional and computed tomography prostate simulation.

Results

Sixty-seven radiation therapy students were provided with a pre-test consisting of 10 multiple choice and true/false questions. Students were then provided with an interactive, 2-hour computer-based educational module. The same 10 multiple choice and true/false questions were then administered in the post-test. Total scores for both tests were evaluated by adding two points for each correct answer and zero points for each incorrect answer. SAS software, V.9.2 (SAS Institute, Inc., Cary, NC) was employed

Figure 5. Example of Module for Prostate Cancer – CT Simulation



for statistical analysis of the data. Analysis of Covariance (ANCOVA) was used to analyze the differences between the pre- and post-test scores. Table 3 summarizes the mean scores and standard deviations of the pre- and post-module test scores.

For unknown reasons, one student did not complete the module pre-test and three students did not complete the module post-test. Thus, students with missing data were eliminated, leading to an actual sample size of 63. The average difference in the test scores describing the change in scores from the pre-test to the post-test for the data from the 63 subjects produced an increase of 2.22 with a variance of 10.3. Testing the null hypothesis that the difference between the pre- and post-module means equals zero was performed with a one-sample t-test giving a very small p-value <0 .001 (t=5.49, df=62), indicating that overall the intervening educational module was effective. The computed p-value indicates the strength of the evidence in the data assuming the null hypothesis is true. P-values less than 0.05 are generally interpreted to have statistical significance, although the cutoff value is somewhat arbitrary and can be adjusted lower or higher as the study objectives warrant.

User Perceptions of the Instructional Module

At the conclusion of the module, students were asked to complete an 11-question survey about their per-

Table 3. Summary of Results Pre- and Post-Test

	# of Students	Number Missing	Mean Scores	Variance (SD)
Pre-test	66	1	15.03	9.0 (3.0)
Post-test	64	3	17.25	7.4 (2.72)
t=5.49, df=62				

ceptions of the educational module (Table 4). The response rate for the questionnaire was high (95.5%). Fifty-eight of the 64 students who completed the survey stated that the module had a positive effect on their learning. With the exception of 6 students, all users indicated that their participation in the module increased their knowledge of the radiation therapy simulation process. Students noted that components of the module that were key to their learning included PowerPoints, quizzes, images, videos, and case studies. Students also noted that the hands-on, interactive approach of the module was beneficial.

Conclusion

Computed tomography has been utilized within the radiation therapy department for many years. With the advent of conformal therapies such as IMRT, the use of computed tomography simulation in radiation therapy continues to increase (Martino, Reid & Odle, 2008). This continued growth, coupled with the overlap of CT with other imaging specialties, has presented many challenges in the education of radiation therapy students (Martino, Reid & Odle, 2008). Educators are faced with the challenge of graduating students who thoroughly understand the concept of radiation therapy simulation so that optimal dose de-

Table 4: Post-Module Survey Data

Post-Module Survey Questions & Responses						
	Strongly Agree	**Agree**	**Disagree**	**Strongly Disagree**	**Does Not Apply**	**Unanswered**
1. The online module was easy to access and navigate.	51.56% (n=33)	43.75% (n=28)	4.688% (n=3)			
2. The module goals and objectives were clearly stated.	50.0% (n=32)	46.875% (n=30)	3.125% (n=2)			
3. The information and materials in the module were presented in an organized manner.	53.125% (n=34)	43.75% (n=28)	1.562% (n=1)			1.562% (n=1)
4. Module materials downloaded in a reasonable amount of time.	42.188% (n=27)	50.0% (n=32)	3.125% (n=2)	1.562% (n=1)	1.562% (n=1)	1.562% (n=1)
5. The media presented in the module worked well (audio files, sound quality, images, and visual media were clear).	37.5% (n=24)	40.624% (n=26)	15.625% (n=10)	6.25% (n=4)		
6. The links to external Internet sites enriched my learning.	25.0% (n=16)	64.062% (n=41)	7.182% (n=5)		3.125% (n=2)	
7. The online case studies and scenarios enhanced my learning.	29.688% (n=19)	68.75% (n=44)	1.75% (n=1)			
8. Pre/post-test questions were clearly stated.	39.06% (n=25)	56.25% (n=36)	3.125% (n=2)	1.562% (n=1)		
9. When required, technical support resolved problems in a timely manner.	10.938% (n=7)	17.188% (n=11)	1.562% (n=1)	1.562% (n=1)	68.75% (n=44)	
10. My participation in this module has increased my knowledge in the radiation therapy simulation process.	29.688% (n=19)	60.938% (n=39)	7.182% (n=5)	1.562% (n=1)		
11. Overall, I would rate this module as:	Outstanding 26.562% (n=17) More than satisfactory 46.875% (n=30) Satisfactory 26.562% (n=17) Less than satisfactory 0% Completely unsatisfactory 0%					

livery and accurate delineation of patient treatment fields is performed.

The statistical analysis of the average difference in the pre- and post-test scores showed an increase of 2.22. The data suggest that the intervening instructional module was effective in increasing student test scores from pre- to post-test. These findings provide educators in radiation science education some assurance that online teaching with the use of a variety of multimedia can be effective. Students can become more actively involved in their learning through the use of various forms of multimedia, interactive assignments, and communication tools utilized within an interactive web-based classroom.

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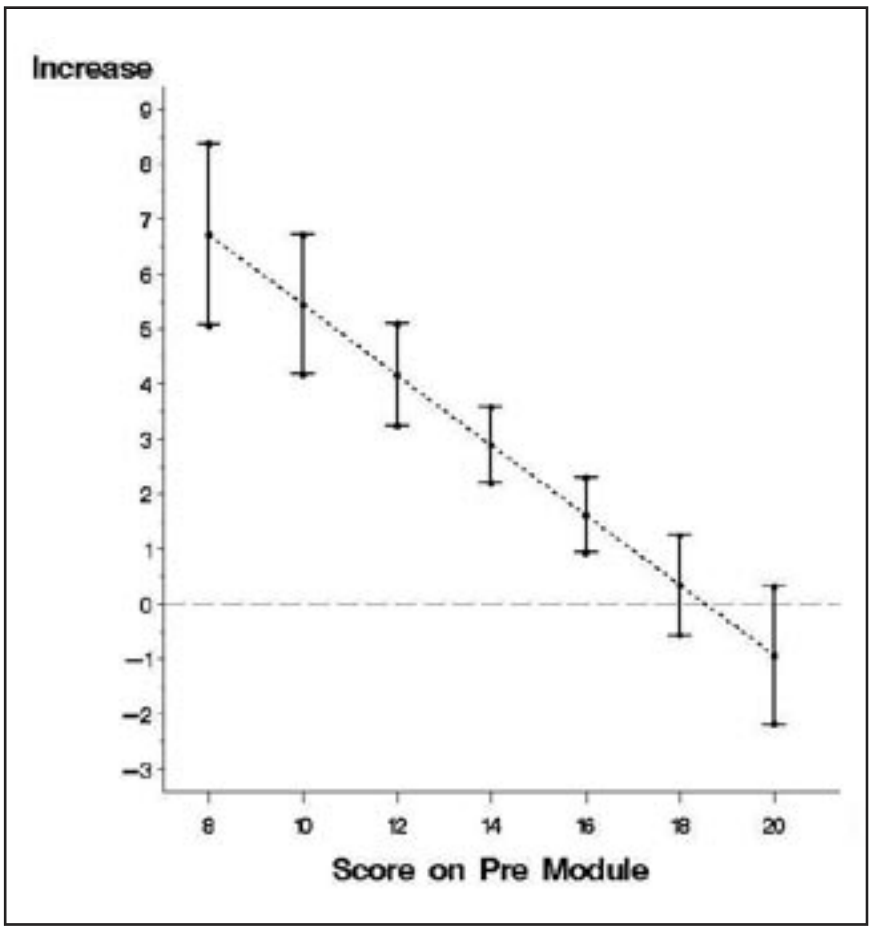
Figure 6. Predicted Change of the Two Test Scores



While the results of this study showed that an interactive, web-based module can be effective in the instruction of radiation therapy simulation, the limitations of the study should be noted. One of the main study limitations involves the fact that the scores are bounded by 0 as a minimum and 20 as a maximum. Analyzing an average difference of 2.22 as it should apply to everyone assumes that all students could potentially change this amount. However, students with test scores averaging 15 on the pre-test would likely experience a greater increase in the score than those who scored 18 or 20 on the pre-test. One method to apply this information is to analyze the individual differences with the student's pre-test score as a covariate.

The ANCOVA of the differences with the pre-test as a covariate produces the following parameter estimates:

$$\text{difference} = \underset{(1.65)}{11.82} - \underset{(0.108)}{0.638}\text{*pre-module} + \text{residual}$$

The residual variance from this model is 6.67 provided that t-tests for the intercept and slope are equal to zero. Both have very small p-values of <0.001, which indicates each coefficient is an important predictor of the observed change. The coefficient for the pre-test, -0.638, with a 95% confidence interval (-0.853, -0.422), indicates that each 2-point increase in the pre-test score (i.e., for each question answered correctly) predicts the amount of increase expected in the post-test score to decrease by -1.25. Therefore, as students' pre-test scores increase, the amount of their expected increase will get smaller. This feature can be observed as the model computes the predicted change at each value of the pre-test with its 95% confidence interval. Predicted values and their confidence intervals are plotted in Figure 6 and listed in Table 5. The predicted increases for pre-test scores of 18 and 20 both contain 0 in their confidence intervals indicating that

Table 5. Predicted Changes of the Test Scores from Pre to Post Test

Pre-module 1	Lower	Estimate	Upper	StdErr	DF	tValue	Probt
8	5.07	6.72	8.37	0.826	61	8.13	<.0001
10	4.17	5.44	6.71	0.634	61	8.59	<.0001
12	3.24	4.17	5.09	0.462	61	9.01	<.0001
14	2.20	2.89	3.58	0.344	61	8.39	<.0001
16	0.93	1.61	2.30	0.341	61	4.73	<.0001
18	-0.57	0.34	1.25	0.455	61	0.75	0.4591
20	-2.19	-0.94	0.31	0.625	61	-1.50	0.1391

test scores which are near the maximum value at the pre-test will not increase at the post-test, whereas those who score low at the pre-test may improve their scores dramatically (e.g., a person having a 10 on the pre-module is expected to improve almost 6 points at the post-module).

Another limitation of the study was the fact that there was no control group. A control group would provide researchers with a baseline for comparison with the experimental group. The study could be improved by demonstrating that a control group had negligible change after the intervention (education) while the treatment group showed observable change. Analysis of this additional data would provide a stronger basis for stating the intervention was very effective.

Pre- and post-test sensitization is another limitation of the study. Information provided during the pre-test may alter the students' expectations of the outcome and have an influence of the experimental treatment (Creswell, 2008). Having identical pre- and post-tests may also affect the outcome as the students may anticipate or retain knowledge from test to test.

There are many possibilities for future research. Options for increasing the validity of future studies would be to add a control group, focus groups, and longitudinal testing. Adding a control group would provide researchers with baseline data to compare to the experimental group. Researchers could further look into student perceptions of similar educational modules by holding focus groups with student participants to gain more insight into the students' feelings about the effectiveness of the teaching methods use. Adding longitudinal or follow-up testing would benefit researchers by providing further information about student retention of the information learned.

The results of this study showed that an interactive web-based educational module can be used effectively to teach radiation therapy students about the simulation process. Based on these findings, the researchers plan to use this module as a template to create additional educational modules that outline the simulation process for other areas of the body. Breast cancer, head and neck cancer, and lung cancer modules are currently in the process of being developed.

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References

Baker, G. R. (2006). Localization: Conventional and CT simulation. *The British Journal of Radiology, 79* Spec No 1, S36-S49.

Bushong, S. C. (2008). *Radiologic Science for Technologists* (9th ed.). St. Louis, MO: Mosby Elsevier.

Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle River, NJ: Pearson Education.

Gross B. D. (1993). *Tools for teaching.* San Francisco, CA: Jossey-Bass.

Grunewald, M., Heckermann, R., Gebhard, H., Lell, M. & Bautz, W. (2003). Compare radiology: Creating an interactive web-based training program for radiology with multimedia authoring software. *Academic Radiology, 10*(5), 543-553.

Gunderman, R., Kang, Y., Fraley, R. & Williamson, K. (2001). Instructional technology and radiologic education. *Radiology, 221,* 1-4.

Harris, M. C. (2002). Is multimedia-based instruction Hawthorne revisited? Is difference the difference? *Education 122*(4), 839-843.

Hicks R. & Gable K. (1998-1999). The learning style profile of Indiana's secondary health occupations students. *Journal of Health Occupation Education, 13*(1).

Hofstetter, F. T. (1995). *Multimedia literacy.* New York: McGraw-Hill.

Jaffe, C. & Lynch, P. (1995). Computer-aided instruction in radiology: opportunities for more effective learning. *American Journal of Radiology 164,* 463-467.

Johnston, J. (2008). Effectiveness of online instruction in the radiologic sciences. *Radiologic Technology 79*(6), 497-506.

Martino, S, Reid, J, & Odle T. (2008). *Computed tomography in the 21st century: Changing practice for medical imaging and radiation therapy professionals.* https://www.asrt.org/media/pdf/educators/ASRT_CT_Consensus.pdf

Moore, M., & Kearsley, G. (2005). *Distance education: A system's view* (2nd ed.). Belmont, CA: Thomson Wadsworth.

Mutic, S. (2001). CT simulation refresher course. Unpublished manuscript.

Mutic, S., Purdy, J., Michalski, J., & Perez, C. (2010). Simulation process in determination and definition of treatment volume and treatment planning. In C. M. Washington, & D. Leaver (Eds.), *Principles and practice of radiation therapy* (3rd ed.). St. Louis, MO: Mosby.

Simonson, M., Smaldino, S., Albright, M., & Zvacek, S. (2009). *Teaching and learning at a distance* (4th ed.). Boston, MA: Pearson Education, Inc.

Sims, R. (2003). Promises of interactivity: Aligning learner perceptions and expectations with strategies for flexible and online learning. *Distance Education 24*(1), 87-103.

Spencer J. and Jordan R. (1999) Learner centered approaches in medical education. *BMJ,* V318. Retrieved on August 15, 2009 from http://www.bmj.com/cgi/content/full/318/7193/1280

Washington, C. M., & Leaver, D. (Eds.). (2010). *Principles and practice of radiation therapy* (3rd ed.). St. Louis, MO: Mosby.

Watherhouse, S. (2005). *The power of eLearning.* Boston, MA: Pearson Education, Inc.

Williams, S.L. (2006). The effectiveness of distance education in allied health science programs: a meta-analysis of outcomes. *The American Journal of Distance Education, 20*(3), 127-141.

Zimeras, S. (2001). Virtual simulation for radiotherapy treatment using CT medical data. Unpublished manuscript.