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ABSTRACT

This paper explains the rationale for utilizing computer-based, hypermedia tutorials for radiology education and presents the results of a field test of this educational technique. It discusses the development of the hypermedia tutorials at Montreal General Hospital (Quebec, Canada) in 1991-92 and their use in the radiology residency program. The tutorials cover: (1) cystic tumors of the pancreas; (2) ectopic pregnancy; (3) physics of x-ray filters; (4) tumors of the posterior fossa in children; (5) anatomy of the temporal bone; (6) diagnosis of arthritis; (7) arterial stenosis and occlusion viewed through ultrasound; and (8) echogenic liver modules. A field test of 6 of the 8 tutorials was conducted over an 8-month period with 24 residents (12 male, 12 female). Twelve residents used the tutorial program while another twelve received traditional lectures on the subject material. Posttest results indicated no significant differences between the two instructional conditions. (Contains 18 references.) (MDM)

The Effectiveness of Computer-Based Hypermedia Teaching Modules for Radiology Residents

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The Effectiveness of Computer-Based Hypermedia Teaching Modules for Radiology Residents

During the period September 1991 to August 1992 eight hypermdia computer-based tutorials for radiology education were developed at the Montreal General Hospital. The design, development, production and evaluation of the modules was carried out by a team comprising medical faculty from McGill University, residents from McGill's network of teaching hospitals, and faculty and students from the Graduate Programs in Educational Technology at Concordia University and Université de Montréal. Postproduction evaluation of the modules was conducted during the period September 1992 to April 1993.

This paper explains the rationale for utilizing a hypermdia appoach in this domain and the expected benefits. The context, including the residency program in radiology and existing traditional teaching methods is outlined. The particular development approach which was employed is described briefly, including organization, processes, tools and funding. Observations concerning the strengths and weaknesses of the approach are provided. The characteristics and functionality of the modules are described. We then outline the evaluation scheme that was followed, including both preproduction and postproduction formative evaluation phases, and provide details of the postproduction evaluation which took the form of a field test. Procedures, tools and analyses associated with the field test are presented. Results are discussed and recommendations for future research and development are elaborated. Overall, findings were positive, with hypermdia generally performing as well as traditional lecture and demonstration methods.

Context

The project was carried out at the Montreal General Hospital under the direction of Patrice M. Bret, Chief of Radiology. The radiology program is a five year specialization which follows accreditation as a general practitioner. Residents are highly selected. There are approximately 24 residents at the 5 teaching hospitals in the Montréal area.

The goal of the current project was to develop and implement improved teaching methods in the radiology program. Radiology candidates must develop knowledge and skills in four areas, namely:

(1) perceptual discrimination and interpretation

(2) factual knowledge (e.g., incidence of different pathologies in different populations)

(3) inferential or diagnostic reasoning

(4) patient and case management

All four forms of competence are developed and refined through supervised case loads. (1) through (3) are addressed instructionally in part through a lecture series and also through "conferences". Conferences generally are one-hour sessions during which as many as five residents are required to diagnose individual cases before their peers and a staff radiologist who has prepared the cases.

This system is somewhat haphazard. Lectures by visiting staff vary from year to year in content and quality of presentation. Conferences are important, but only one or two residents are truly actively participating at each session. Our informal observations of conference sessions revealed a low level of attention from some non-participants. Also, preparation time for both conferences and lectures is quite substantial and staff radiologists have less time at their disposal for these tasks than is desirable.

Hypermedia for Radiology Training

Hypermedia has enormous potential as an instructional tool in the domain of radiology (Ackerman, 1992; Greenes, 1992; Jaffe & Lynch, 1992; Lesgold and Katz, 1992), especially with regard to the first three objectives listed above: development of perceptual and inferential skills and acquisition of factual knowledge. More explicitly, computer-based hypermdia offers the following possibilities:

•a highly interactive form of instruction that guarantees active learner participation;

•the capability of presenting images (CTs, MRIs, Doppler images, X-rays) and of highlighting these images in different ways to train residents in perceptual discrimination tasks, and to test interactively their abilities;

•the ability to present cases, and to pose cases for solution;

•flexible instructional strategies including simulation, case-based learning, as well as discovery learning and tutorial modes;

•the possibility of a seamless environment for study with interconnected on-line glossaries, bibliographies and search functions;

•facilities for annotating, saving, and printing images; generating bibliographies; saving and printing comments and notes, and;

•the capacity to exploit thematic connections among concepts and cases through the structural flexibility of hypermedia systems (a capability which Spiro et al. (1989, 1991, 1992) argue is especially important in ill-structured domains)

By taking advantage of these possibilities, the following benefits for the project were anticipated:

•improved curricula in radiology

•standardization of quality and content of core curricula

•improved learning through sound instructional design and interactive learning strategies

•ongoing improvement of instruction through formative evaluation (including on-line collection of user data)

•increased understanding of variables affecting learning in hypermdia in medical education

•dissemination of tools (a shell) and transfer of development methodologies to radiology programs throughout Canada

•reduced instructional preparation time for Faculty

•increased availability of explicit training to interns

Review of Related Projects

Despite the apparent potential of hypermdia for this domain, there are relatively few existing projects which have been evaluated and reported. Those which have been reported are of limited scope.

Among studies which have been conducted we find the following: Moore, Kathol, Zollo and Albanese (1993) assessed the effectiveness of a videodisc film file compared with a conventional film file for teaching radiology to medical students. One hundred and thirty-four (134) fourth year medical students studied 116 cases selected from the American College of

Radiology Learning File. Material comprised 58 skeletal cases and 58 chest cases. One half the students studied the skeletal cases on film, the other half on vidoedisk. The conditions were then reversed for the chest cases. There was no significant difference between the two conditions regarding learning. However, students utilizing film reported their perception of a superior learning experience in terms of amount learned, convenience of use and ability to detect lesions. This is an interesting study insofar as it provides some justification for the use of lower resolution media for teaching purposes. However, the interactive and advanced navigational features afforded by the technology were not exploited in the design of this particular project.

D'Allesandro, Galvin, Erkonen, Albanese, Michaelsen, Huntley, McBurney and Easley (1993) compared the instructional effectiveness of a hypermdia textbook (HyperLung) of a lung disease with a lecture. HyperLung consists of a sophisticated hypermdia "pop-up" textbook comprised of a table of contents, discrete chapters, indices, a dictionary, on-line testing, text search and annotation capabilities. Forty-nine (49) staff and residents in radiology were randomly assigned to receive instruction either by HyperLung or by lecture. Both grc ıps recieved the same informational content and were tested before and after instruction. There were no significant differences in learning between the two groups.

This is perhaps the closest project to the evaluation reported in this paper. However, the Montreal General Hospital project has a smaller, presumably more homogeneous sample (residents only), and provides longer exposure to the "treatment" conditions.

Jaffe, Lynch and Smeulders (1989) developed a hypermedia program on echocardiography to be used as the primary instructional tool for achieving an intermediate level of clinical expertise. It consists of a user-controlled learning environment with random access to 54,000 images and 1,200 clinical items. This module has proved successful in providing a uniform basic curriculum in echocardiography. After five to ten hours of independent study with this module, residents are said to "have achieved an intermediate level of expertise and need less tutoring from the attending physician" than previously (Jaffe *et al.*, p. 479). An objective qualitative assessment of skill acquisition is reported to be in progress. However, the authors do not reveal how the reported improvements in skill and performance were measured.

Wenzel and Gotfredsen (1987) studied retention of theoretical knowledge after computer-assisted instruction in intraoral radiography. No significant differences were found between treatment and control groups on immediate or delayed (three months, 18 months) posttest measures, though both groups showed significant differences on pretest versus immediate posttest measures. Instrumentation comprised 20-item multiple choice tests.

Starkshall, Riggs and Lowther (1986) report the development and informal assessment of a computer-aided instructional module for radiological physics. The program appears to be a protoype. Informal feedback collected from physicists, residents and technology students focused on educational value and user friendliness. The feedback reported was positive and supports the use of the technology in the curriculum.

Several features distinguish the Montreal General Project from the projects and evaluations documented above. In particular our project involves several learning objectives, a variety of materials and themes presented through one standard interface, and a relatively long duration with some 20 hours of material delivered over a six month period.

While there are weaknesses in the evaluation design and instrumentation, as discussed later in this paper, overall the approach is more rigorous than the evaluations described above carried out by other groups. In our view, our evaluation provides more reliable and more detailed evidence of the applicability of computer-based hypermdia to instruction for radiology programs than the other projects which have been reported in the literature. Important features of the evaluation plan include analysis of impact on learning by type of objective, residency level and instructional method, a field implementation, and a collaborative learning situation for the field implementation which is described below.

The Tutorials

The modules developed during the project cover the following topics: (1) Cystic Tumours of the Pancreas, (2) Ectopic Pregnancy, (3) Physics of X-Ray Filters, (4) Tumours of the

Posterior Fossa in Children, (5) Anatomy of the Temporal Bone, (6) Diagnosis of Arthritis, (7) Arterial Stenosis and Occlusion Viewed Through Ultrasound, and (8) Echogenic Liver Modules. Each module contains two to four hours of content, divided into chapters. A standard interface and a standard set of functions were designed for use in conjunction with all modules and these were incorporated in a shell programmed in Supercard on the Macintosh, which served as the basic authoring tool. A medical market scanner (an Omniscanner equipped with a back light) was used for digitizing directly radiological images. Sound (for Doppler) was digitized using MacRecorder. Standard draw programs such as MacPaint and Adobe Photoshop were used for creating graphics. Macromedia's Director program was used for animations. The digital video standard was Quicktime.

The shell was developed by a staff radiologist and the interface was subjected first to expert review and subsequently, with some content in place, to testing with the assistance of graduate students from Concordia and Université de Montréal to further determine usability. Three graduate students from Concordia were employed in the role of "end-users" for usabilty testing with a representative module. Two strategies were employed: task-based evaluation and an evaluation grid. In the task-based component of the exercise, students were required to obtain certain specific information from the module or to perform a particular task (e.g., paste an image to the scrapbook and print it). Using the evaluation grid, students evaluated the module along several dimensions using a proscribed checklist that comprised Likert-scale items measuring ease of use, quality of graphics and the degree of usefulness of specific features.

A staff radiologist and one senior resident were then assigned to develop the content and finally actually to produce each module. During production, the staff radiologist who developed the shell was available to provide support to the different development teams. Each module underwent ongoing formative evaluation for content accuracy and for consistency in presentation style and graphics. Consistency within and among modules was verified at regularly scheduled group presentations of work in progress attended by staff developers and instructional technologists.

The core content of each module corresponds to a specific lecture scheduled during the

1992-1993 sessions. The staff radiologist assigned to each module was the same individual who would deliver the lecture.

Some modules cover all three aspects of radiology training referred to above. Some cover only two (leaving out diagnosis or perceptual training), while one module, the one concerning physics of X-rays, covers only factual or theoretical knowledge.

Modules incorporated digitized images (computed-tomograpgy [CT], x-ray, magnetic resonance images [MRI], ultrasound), animations, digitized sound (e.g., doppler effects), text, and graphics (medical illustrations). Standard features included glossaries, on-line references and abstracts hyperlinked to the content; a scrap-book where users could file images and text; a notebook, graphic tools and a text editor to annotate contents pasted to the scrap book; electronic book mark; chapter and node indices; text search; keyword search; hyperlinks among content presented via a navigation board displaying related nodes; on-line help; and print functions for bibliographies, scrap book and notes.

Although functionally and technically relatively sophisticated, the modules were developed and produced largely by medical staff. Instructional technologists provided minimal production support. They contributed to a greater extent to the design. The project was kept on schedule by the Chief of Staff of Radiology. This is a significant point in the organization of the project. It is estimated that over 6,000 person hours were spent in development and production phases over a three-year period. Cooperation and motivation of staff radiologists and residents, who are heavily burdened with cases and teaching responsibilities, could only be secured and maintained over time through the priority assigned to the project by the Chief of Staff. Final production values were reasonably professional as judged by the instructional technologists involved.

Method

Postproduction Evaluation

A field test of the eight modules was conducted over an eight month period. A stratified random sampling divided the available group of residents (n=24) into two groups, with equal numbers of senior and junior residents in each. One group was assigned to the hypermdia condition, the other was to experience traditional lectures. No pretesting was employed; prior knowledge was treated as a random variable.

Originally the plan was to use a 2 x 2 x 3 x 5 x 8 mixed repeated measures design to assess differences in learning of different categories (perceptual, factual, and diagnostic reasoning) between the two groups on immediate and delayed posttest administration, based on residency level on each of the eight modules. Delayed posttesting was not feasible owing to logistic problems associated with assembling residents from the various teaching hospitals at the same time on so many occasions.

Given sample size and variable mortality over the six posttests, six independent t-tests were conducted to compare groups on posttest scores. Six one-way ANOVAs were conducted to analyse differences based on residency level.

Independent t-tests were employed to investigate which individual items differentiated the two treatment groups.

Subjects

Twenty-four (24) residents in radiology at McGill's five Montreal area teaching Hospitals participated. There were 12 females and 12 males. The sample represents all available residents during the period of the study. Participation in the study was urged by the Chief of Staff of Radiology, and no resident declined to participate.

Instruments

Posttests were designed to be as similar in format as possible. Each posttest comprised multiple choice and short answer items. One test (Arterial Stenosis and Oclusion Viewed Through Ultrasound) included photographic prints of ultrasound images with areas to be identified and outlined by subjects. Each test was constructed by a lecturer with assistance from the instructional technologists. Tests were reviewed to ensure adequate sampling of the content, and to verify that content was contained in both lectures and hypermdia. Hypermedia modules contained additional content not intended to be presented in the lectures. This content was excluded.

Pilot testing of several of the postests was conducted with residents who were not included in the study in order to evaluate clarity and duration. Guidelines for format and length of the posttests were created on the basis of the validation of the first posttest. There was not a sufficient number of residents available to allow for formal pilot testing of tests for all six modules.

Scoring of test results was carried out by the lecturer responsible foı the content. Tests were identified only by a code number to ensure impartial evaluation. For non-objective test items (e.g., short answer diagnoses, precise identification of pathological features in images) with a range of possible scores, the lecturer provided an evaluation grid, and items were scored by both lecturer and instructional technologist. Inter-rater reliablity for this scoring procedure was set at .90 and achieved.

Procedure

On the six testing days, which occured at one month intervals, all residents were assembled at the Montreal General Hospital in a meeting room. They were instructed to go either to the lecture hall or the hypermdia lab, according to their random assignment. The lectures were scheduled to last one-hour. The hypermdia sessions were concurrent with the lectures with the same duration. At the end of the one-hour presentation period, all subjects were reunited in the meeting room and the tests were administered during a 45 minute period.

Subjects were surveyed by the instructional techologists during the test administration of the test. They were instructed to place the last four digits of their phone number on the cover sheet for identification purposes, and their residency level (year one through five) on the back of the last page. Completed tests were returned to the invigilators, who recorded the completion time.

On the first testing day, the objectives of the study were explained to participants. In particular, they were informed that the results of the testing were not a formal component of their evaluation in the residency program, and that the primary objective was to evaluate the two instructional systems. Those not in the hypermdia condition were informed that access to the hypermdia materials would be provided to them after testing.

A survey revealed that no participant in the hypermdia condition had ever experienced computer-based instruction. There was little experience of application software other than clinical applications. Hence, in preparation for the hypermdia condition participants were provided with a twenty-minute training session. For this session, a self-instructional module was prepared using the same shell and interface as the medical education modules. During the training session the instructional technologists were present to provide additional support to the participants.

In the hypermdia condition, participants worked in groups of two or three at workstations. They communicated freely during the sessions, within their groups. On-line traces recorded content that was accessed and time spent in the module. During the hypermdia sessions participants were free to access any content, but were informed which chapters corresponded to the lecture material and would be directly relevant to the subsequent test.

The order of the modules was determined by the availability of the lecturers. There was no obvious relationship of dependency among the contents of the different modules.

Results

While eight modules were developed, only six were included in the study, owing to time constraints and availability of team members and subjects. The six were: (1) Cystic Tumors of the Pancreas, (2) Ectopic Pregnancy, (3) Physics of X-Ray Filters, (4) Tumors of the Posterior Fossa in Children, (5) Anatomy of the Temporal Bone, and (6) Arterial Stenosis and Occlusion Viewed Through Ultrasound.

Descriptive statistics (sample sizes, group means, standard deviations, maximum scores on posttests) for the six modules are presented in Table 1 for the two conditions. The SPSSx program *Frequencies* was employed to assess assumptions of univariate normality and to detect outliers. Tests for univariate normality were satisfactory.

Insert Table 1 about here

Of the six independent t-tests comparing posttest scores (see Table 2), only the one associated with Tumours of the Posterior Fossa was significant ($t[17] = 4.04$, $p < .05$). However, irregularities regarding the length, format (short answer, only) and design of the posttest (redundant items), lead us to disount this result.

Insert Table 2 about here

Of the six one-way ANOVAs (see Table 3) conducted to investigate differences by level of residency only the one addressing Physics of X-Ray Filters was significant ($F[3,19] = 3.4$, $p. < .05$). Subsequent posthoc analyses in the form of independent t-tests indicated the differences related to item five, a factual recall item which asked the resident to identify the material used for the node of an x-ray unit, the reasons why the material is used and at what kVp characteristic x-rays emerge. Junior residents outperformed seniors on this item.

Insert Table 3 about here

Independent t-tests administered for items in each module to determine which individual items discriminated between the groups revealed seven additional significant items (see Table 4).

Insert Table 4 about here

Discussion

Basically, we found no significant differences between instructional conditions or by residency level. As indicated above, only the module Tumours of the Posterior Fossa, revealed differences based on residency level and this result should be discounted because of problems associated with the length, format and design of the test. Only one module yielded significant differences based on instructional condition: Physics of X-rays. However, this module did not cover all three types of learning objectives.

The results do not appear generally to be due to a ceiling or floor effect. Most modules have mean scores between 50 and 65 % of total possible scores, with reasonaby large standard deviations (see Table 1). The lowest mean scores are found in Cystic Tumours of the Pancreas where they are about 40% which might be interpreted as a floor effect. This model did not have any items which discriminated between treatment conditions.

The overall results of the evaluation are consistent with other studies which have investigated computer-based applications in radiology education. The methodology and sample are different than other reported studies. Other studies have included larger but less homogenous samples, different technologies (videodisc), lack details concerning instructional design approach, granularity, are merely one shot post-test designs, or use different measures (or do not report measures).

Despite the limitations in our evaluation described above the present field study provides strong evidence that technology-based instruction can be as effective as traditional lectures in delivering complex or refined subject matter to radiology residents.

Table 4 lists those postest items for which the two treatment groups differed significantly. The items concerned fall in two categories: factual and visual discrimination. Two factual items favoured the hypermdia treatment, while two favoured the control group. In the module concerning Arterial Stenosis and Occlusion, the control group outperformed the hypermdia group on three visual discrimination tasks. In the Physics of X-ray Filters module, the hypermdia group outperformed the control group on a theoretical question.

While it is difficult to draw conclusions from these few results, it is interesting to note two things. First, the results for the three visual discrimination tasks are interesting. The hypermdia system provides more images than were presented during the lecture, and these images are highlighted and annotated in sophisticated ways. We therefore expected the hypermdia group to outperform the lecture group on this class of tasks. The results suggest that the issue of the difference in resolution of images displayed in the software with regular film output, and its potential impact on transfer, should be revisted. In the visual discrimination tasks residents worked from copies of film. Film resolution is over 1000 dpi, while images incorporated in the modules are scanned down to 600 dpi and then displayed on a 72 dpi screen. This is a significant reduction in quality that may have a significant impact on feature identification and discimination.

Secondly, the hypermdia module addressing the physics of x-ray filters made extensive use of dynamic visual displays (animations and Quicktime clips) to illustrate theoretical principles. The superior performance of the hypermdia group on a factual item addressing a theoretical issue is thus encouraging, insofar as it indicates the effectiveness of this strategy.

Recommendations for Future R&D

With a no-significant-difference result, one can conduct a simple cost-effectiveness or cost-benefit analysis to decide whether the technological approach is worthwhile. While the initial effort to develop the eight modules was considerable, the benefits are obvious, as outlined above. The material is available on demand, while the content and quality of delivery is standardized. With the present shell it is relatively easy to add new chapters or content to existing modules and with the development and production expertise acquired within the radiology department during the course of the project creation of new modules should be possible with less effort. Cost-effectiveness is enhanced by the circumstance materials can be shared with radiology programs across Canada. On the other hand, it must be acknowledged the "freeware" approach limits the possibilities of developing and marketing the materials in a commercial form, to generate revenues for further work.

In assessing the strategy for funding this project, it should be remembered that a major goal was to develop a standard shell with a fixed interface which might achieve widespread use. One of the major problems associated with the growing body of published commercial software for medical education is that there is a great deal of variability in functionality and interface design. Standards and conventions yield efficiencies for both developers and end-users (learners). We reasoned that a robust design which could "satisfice" requirements for delivering content related to radiology education would be a useful contribution to software development in this area.

Funding for this project was minimal. $40,000 was provided by the Canadian Radiological Association and Sterling Winthrop pharmaceutical company. Despite this limited funding, over 20 hours worth of material was developed. The project demonstrated the feasibility of in-house development and production within a teaching hospital, with limited start-up capital. For the moment, until the market matures, development of usable products for smaller specialized market segments will continue to depend on the efforts of commited in-house developers.

Future evaluations should utilize truly standardized posttest instruments that have been assessed for reliability. This was not strictly possible in our evaluation given the limited sample available within the McGill teaching hospitals. A more representative sampling of the three types of learning objectives would also be desirable.

As mentioned, the study involved group utilization of hypermdia. No attempt was made to exploit this in the design of the modules and their functions, and groups were formed randomly and changed to some extent over time, based on absenteeism. Further studies might control for this variable, or investigate the impact of the variable on performance and attitudes.

The decision to utilize groups in the delivery of the hypermdia materials was based on three factors: (1) the nature of radiological activities during residency, which are typically group-based, (2) differences among participants regarding experience with computers, and (3) availability of appropriate computer resources (we didn't have 15 high-end MacIntosh computers).

In a strict sense, the group dimension is clearly a confounding element in the field study (did residents learn from the hypermdia materials or from their interactions with peers?). But from an evaluation standpoint, the issue is not critical -- unless one wishes to generalize to use of the materials on a strictly individual basis.

Finally, future developments of the applications should entertain the following recommendations:

- The programs should exploit hypertext capabilities to a greater extent, incorporating more mini-cases (following Spiro, 1989;1991).

- Enhancements to program functionality should be based on a detailed analysis of realistic learning and clinical activities in radiology, following principles of cognitive apprenticeship and situated learning. Such an analysis would allow implementation of a cognitive apprenticeship strategy with variable levels of support for learning and performance

(Collins, Brown & Newman, 1989) and would be in line with recent thinking about the need to accomodate situated aspects of complex problem-solving activities in ill-structured domains, including social and cultural dimensions (Clancey, 1993).

•Further recommendations from formative evaluation of the interface, concerning aspects such as standardization of location of visual versus textual information, should be implemented.

•The possiblities offered by multiple windows for promoting visual acuity based on multiple image comparison should be explored. The present software offers only limited comparison of images with two per screen, or with comparison images on successive screens or interchangeble within a window.

•The issue of the impact of lower resolution gray scale images on visual perception tasks and its impact on transfer to operational radiological conditions should be investigated.

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Table 1

Descriptive Statistics for the Six Hypermedia Modules

	Sample Size		Mean (SD)		
Hypermedia Module	**Hypermedia Group**	**Traditional Teaching Group**	**Hypermedia Group**	**Traditional Teaching Group**	**Maximum Possible Score on the Posttest**
1) Arterial Stenosis and Occlusion Viewed Through Ultrasound	10	14	31.60 (10.46)	32.29 (8.18)	64
2) Physics of X-Ray Filters	11	13	33.18 (8.68)	31.62 (7.08)	50
3) Ectopic Pregnancy	10	12	26.30 (4.64)	29.83 (3.76)	52
4) Cystic Tumors of the Pancreas	6	15	15.83 (3.82)	17.20 (2.51)	42
5) Anatomy of the Temporal Bone	8	13	14.25 (3.88)	15.08 (5.28)	30
6) Tumors of the Posterior Fossa in Children	6	13	6.50 (1.23)	9.08 (1.32)	10

Table 2

Independent t-tests Comparing Groups on Posttest Scores

	Mean (SD)		T-test
Hypermedia Module	**Hypermedia Gr. up**	**Traditional Teaching Group**	**Value**
1) Arterial Stenosis and Occlusion Viewed Through Ultrasound	31.60 (10.46)	32.29 (8.18)	0.18
2) Physics of X-Ray Filters	33.18 (8.68)	31.62 (7.08)	0.49
3) Ectopic Pregnancy	26.30 (4.64)	29.83 (3.76)	1.97
4) Cystic Tumors of the Pancreas	15.83 (3.82)	17.20 (2.51)	0.97
5) Anatomy of the Temporal Bone	14.25 (3.88)	15.08 (5.28)	0.38
6) Tumors of the Posterior Fossa in Children	6.50 (1.23)	9.08 (1.32)	**4.04***

* $p < .05$

Table 3

One-way ANOVAs Comparing Residency Level on Posttest Scores.

	Mean (SD)		
Hypermedia Module	**Hypermedia Group**	**Traditional Teaching Group**	**F value**
1) Arterial Stenosis and Occlusion Viewed Through Ultrasound	31.60 (10.46)	32.29 (8.18)	$F(4,19)=2.54$
2) Physics of X-Ray Filters	33.18 (8.68)	31.62 (7.08)	**$F(3, 19)=3.44^{*}$**
3) Ectopic Pregnancy	26.30 (4.64)	29.83 (3.76)	$F(3, 18)=0.34$
4) Cystic Tumors of the Pancreas	15.83 (3.82)	17.20 (2.51)	$F(4,16)=1.56$
5) Anatomy of the Temporal Bone	14.25 (3.88)	15.08 (5.28)	$F(3, 12)=0.18$
6) Tumors of the Posterior Fossa in Children	6.50 (1.23)	9.08 (1.32)	$F(3, 13)=0.71$

* $p < .05$

Table 4

Item analysis

Hypermedia Module	Posttest Question Number	Mean Score of Hypermedia Group	Mean Score of Traditional Teaching Group	T-test Value
1) Arterial Stenosis and Occlusion Viewed Through Ultrasound	Q1	3.60	0.79	**5.12***
	Q14	0.70	2.82	**3.61***
	Q15	0.20	1.43	**4.05***
	Q16	0.70	1.25	**0.20***
2) Physics of X-Ray Filters	Q5	4.00	3.07	**2.21***
3) Ectopic Pregnancy	Q3	1.30	2.25	**2.82***
	Q7	0.60	1.00	**2.45***
	Q15	1.20	0.50	**2.97***

* $p < .05$