Embedding Medical Student Computer Tutorials into a Busy Emergency Department

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Abstract

Objectives: To explore medical students' use of computer tutorials embedded in a busy clinical setting; to demonstrate that such tutorials can increase knowledge gain over and above that attributable to the clinical rotation itself.

Methods: Six tutorials were installed on a computer placed in a central area in an emergency department. Each tutorial was made up of between 33 and 85 screens of information that include text, graphics, animations, and questions. They were designed to be brief (10 minutes), focused, interactive, and immediately relevant. The authors evaluated the intervention using quantitative research methods, including usage tracking, surveys of faculty and students, and a randomized pretest-posttest study.

Results: Over 46 weeks, 95 medical students used the tutorials 544 times, for an overall average of 1.7 times a day. The median time spent on completed tutorials was 11 minutes (average [SD], 14 [±12] minutes). Seventy-four students completed the randomized study. They completed 65% of the assigned tutorials, resulting in improved examination scores compared with the control (effect size, 0.39; 95% confidence interval = 0.15 to 0.62). Students were positively disposed to the tutorials, ranking them as "valuable." Fifty-four percent preferred the tutorials to small group teaching sessions with a preceptor. The faculty was also positive about the tutorials, although they did not appear to integrate the tutorials directly into their teaching.

Conclusions: Medical students on rotation in a busy clinical setting can and will use appropriately presented computer tutorials. The tutorials are effective in raising examination scores.

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Keywords: computer-assisted instruction, medical education, emergency medicine, undergraduate medical education, multimedia educational models, teaching

In their senior year, medical students leave the classroom to learn in clinical settings using an apprenticeship model. They gain invaluable experience from their patients, peers, and preceptors. In addition to case-based learning, students are also expected to gain knowledge by reading about their cases.

Computer-aided instruction (CAI) can offer excellent instructional strategies for the clinical learning setting.[1,2] For example, computer graphics allow visual explanations that are potentially more efficient and effective than those offered by standard printed texts. Animations allow students to visualize functional relationships that are difficult to describe using text or static figures. Videos of clinical findings (e.g., seizures) or procedures (e.g., lumbar puncture) allow an aggregation of experience that would otherwise take a considerable amount of time.

A number of studies have determined that CAI can be a valuable learning resource in medical education.[3,4] Research into the effectiveness and acceptance of CAI has focused largely on the use of computers versus the more traditional methods, such as lectures and text.[5,6] Studies of the effects of technology on teaching and learning have demonstrated the benefits of CAI in the didactic environment, not only for the purposes of student achievement through the measurement of test scores[7] but also in relation to the development of cognitive skills, such as problem solving and decision making.[7,8]

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While these research syntheses have shown the value of CAI in classroom-type settings, what is less clear is whether these novel instructional strategies can be implemented in a clinical setting such as the emergency department (ED). Our study was concerned with improving learning in the clinical setting through the intervention of timely, relevant resources that students can access at critical moments as they are engaged in on-the-job learning as practicing clinicians.

There is an excellent theoretical basis for why such an intervention should work well in an ED. Situated learning theory holds that learning is a dynamic process that depends heavily on time, place, and social interaction and collaboration.[9,10] Knowledge acquisition should occur within the same domain of activity as its real-world application, with isolated book learning or lectures being too far removed from context to be as effective.[11,12] Good instructional design is essential for situated learning to be effective.[13,14] In particular, careful management of the learning environment so as to distribute the learning tasks to the components of the system best suited to their delivery is likely to be rewarded with optimal learning.[15]

Mayer has put forth a cognitive theory of multimedia learning that supports its use in preference to more traditional methods. He proposes that multimedia tutorials can decrease cognitive load and thus increase knowledge gain.[16] For a given amount of information, learning is augmented if the information is appropriately divided between graphics (still or animated) and words (spoken or written). CAI can also improve knowledge processing by using an interactive style of presentation that encourages deeper processing than do more passive methods, such as reading texts or viewing images.[17]

Many have noted that the flexibility of CAI is one of its main advantages because it allows students or medical educators to choose the timing, place, and pace of learning.[1,15,18] The approach known as *just-in-time learning* offers a new dimension to studies into the efficacy of CAI.[19] Knowledge is presented in the workplace in a modularized form that is "readily acceptable and instantly applicable."[20] In this way, learners seek to acquire knowledge when they most need it and when their motivation is immediate.[21] Just-in-time learning fits nicely within the theoretical framework of situated learning and has specifically been identified as a viable and cost-effective method in medical education.[22]

For these reasons, just-in-time learning, in the form of CAI, appears well suited to the clinical learning setting, where medical students shift constantly between the cognitive apprenticeship of working in authentic situations with clinical preceptors and the self-study activity of seeking and retrieving useful information that can be applied instantly to the tasks at hand.

We hypothesized that, by using focused, brief computer tutorials, we could effectively supplement the students' learning of clinical medicine on a senior-year clinical rotation. We sought to demonstrate that this technique is feasible, that is, that the medical students would use the tutorials and that the tutorials could increase knowledge gain over and above that attributable to the clinical rotation as already constituted.

METHODS

Study Design

This was an impact evaluation of the tutorials using quantitative measures. Research methods included log file analysis, exit surveys of the students, a faculty survey, and a randomized controlled trial measuring knowledge gain over the course of the rotation. This study was approved by the Montreal Children's Hospital Institutional Review Board. We obtained informed written consent from all participants.

Study Setting and Population

The study took place in the pediatric ED at the Montreal Children's Hospital during the students' outpatient rotation. The pediatric ED has an annual census of 85,000 visits. Ten full-time emergency medicine faculty, as well as community pediatricians who work in the pediatric ED part-time, supervise approximately ten undergraduate and ten postgraduate trainees per month. Medical students are taught using a variety of teaching methods besides bedside teaching, including daily lectures and weekly small group tutorials. There was, however, very little in the way of CAI materials available to them.

All senior medical students at McGill University have a mandatory two-week rotation in the pediatric ED at the Montreal Children's Hospital, amounting to six to eight shifts. The study ran for 14 months, recruiting students on the first day of the rotation. Participation was entirely voluntary. None of the study information was used in any of their evaluations.

Study Protocol

Tutorial Design Principles. We wrote six computer tutorials on the subjects listed in Table 1. The subjects were chosen specifically with the following in mind: that they be common cases that will be seen during virtually every pediatric ED shift, and that they be important to the practice of a general practitioner. Each of the subjects is found in published curriculum guidelines for medical students.[23] We kept the following design principles in mind:

- That they be brief. We knew from a previous study that trainees are not able to complete long computer tutorials while on duty but that they do have enough time to complete brief tutorials.[24]
- That they be focused. Within brief tutorials, comprehensive didactic presentations in a standard textbook format would be neither possible nor desirable because it would not take maximal advantage of the time available.
- That topics be chosen where computer-mediated instructional strategies are particularly effective. For example, computer graphics make learning x-ray interpretation engaging and efficient; animations make learning the osmotic advantages of oral rehydration solutions easier.
- That they supplement case-based learning. We had in mind that the student would have potentially seen a patient with the given condition and would now be using the tutorial to bolster their learning from the case. Thus, the tutorials were tailored to the cases seen in our setting.

Table 1
List of Tutorials and Description of Their Attributes

Tutorial Subject	Educational Objective	No. of Screens	Instructional Strategies	Examination Question (Abbreviated)
Cervical spine x-ray interpretation	Procedure for the systematic interpretation of cervical spine x-rays in trauma patients	85	Schematic illustrations Diagnosis of unknown x-rays	A 4-year-old child fell 4 feet off the monkey bars. . . . List what features of the x-ray you feel are important.
Febrile seizures	Knowledge of diagnosis and management of febrile seizures	33	Multiple-choice questions with immediate feedback	A 3-year-old girl has just had a febrile seizure. Her eyes rolled up and then all four limbs began to rhythmically jerk. It lasted for 15 minutes. [What is] . . . the risk of further convulsions and [can] anything can be done to prevent them?
Fever without source	Knowledge of diagnosis and management of febrile children 3–36 months of age	50	Serial exposition of knowledge content Hypothetical case management	A 1-year-old child presents with a temperature of 40°C for two days. . . . Do you believe this child needs any laboratory investigation? Explain your response.
Growth plate fractures	Knowledge of normal anatomy and patterns of injury of growth plates	55	Schematic illustrations Diagnosis of unknown x-rays	Draw the Salter–Harris classification. Include labels of the anatomic structures. How is this classification useful?
Oral rehydration solutions	Knowledge of the physiology and advantages of oral rehydration solutions	38	Schematic illustrations Animations Matching exercises	Compare the composition of Pedialyte with apple juice. What factors make Pedialyte a better choice than diluted apple juice for oral rehydration?
Tissue adhesives	Procedure for repairing a laceration with tissue adhesive	38	Serial exposition of procedure Multiple-choice questions	A 1-year-old child has a 1-cm laceration over his right eyebrow. You decide to glue it using Dermabond. What are the potential pitfalls and complications?

Tutorial Creation. We used the software authoring language Toolbook II Instructor version 6.5 (SumTotal Corp., Mountain View, CA). Independent content experts reviewed all tutorials, and the tutorials were each pilot tested on at least two students and two residents. The tutorials were then revised, with all of the changes suggested by the reviewers being incorporated into the tutorials and reflected back to them. Disagreements between the author and the reviewer were resolved by consensus.

The tutorials ranged in length from 33 to 85 screens, taking 5–15 minutes to complete. The content was displayed in a linear screen-after-screen fashion, although students could skip to any part of the tutorial using a "map" function. They were designed to be as interactive as possible, with multiple-choice questions with immediate feedback, matching exercises, and x-ray unknowns. Animations, schematic drawings, and pictures were all used, but there was neither video nor sound.

Tutorial Implementation. We installed the tutorials on an Intel-based computer running the Microsoft Windows (Microsoft Corp., Redmond, WA) operating system in the main part of the nursing station where clinicians complete their written charts. The area is neither quiet nor out of the main stream of activity, but it allowed students to complete the tutorials without leaving the department. The computer was not connected to either the Internet or the hospital information system.

The computer tutorials were only available on the pediatric ED computer station. Students could access them either during a shift or on their own time. Each student had his or her own preassigned log-in identification and password. There were six computer tutorials in total, but we restricted each student to only three of the tutorials during his or her rotation. Which three tutorials were available to a given student was determined for each student before the trial started using a random number generator. After signing in, the student would see which tutorials were available. Access to the other three tutorials was enabled after the participating student had completed the posttest. The tutorials were also available to the rest of the pediatric ED community using generic log-ins for residents, nurses, staff physicians, and an "other" category.

We advertised the presence of the tutorials to the students at their orientation and to the faculty using posters in the ED, a colorful screen saver on the computer itself, and memos sent to each faculty member with his or her monthly schedule. We did not specifically describe the tutorial content but presented highlights at divisional meetings and made it clear that the faculty could peruse the tutorials at any time.

Outcome Measures

The principal outcome measures were the number of times the tutorials were used, as well as knowledge gain on an examination administered before and after the students' two-week rotation. Secondary outcome measures included 1) for the log file analysis: the rate of tutorial completion and its dependence on time of day and length of tutorial as well as the duration of use per interaction; 2) for the knowledge gain trial: dependence of knowledge gain on tutorial timing and tutorial subject; 3) for the student survey: attitudes toward the tutorials overall and toward specific features of the system, such as number of tutorials and their location, as well as opinion on the degree to which the tutorials helped them learn; and 4) for the faculty survey: attitudes toward the tutorials and to what extent they incorporated the tutorials into their teaching.

Knowledge Gain Examination. Participants completed the same six-question short-answer examination on days 1 and 12 of the rotation during a one-hour proctored session (Table 1). The questions on the examination were developed by one of the investigators and reviewed by two pediatricians for face validity. Their suggestions were incorporated into a revised test that was then used with 20 students during a study "burn-in" phase. Wording that was unclear was further revised for the version of the examination used in the study.

After the study was completed, the examinations were deidentified and given to three physicians for marking. The markers were not given an answer key. Only one had direct knowledge of the content of the tutorials. Each was blind to the pretest or posttest status of the examination being marked as well as to which computer tutorials had been completed by any given student.

Compliance with randomization was determined by comparing the tutorial topics to which an individual student had been randomized with whether the student reported doing the tutorial on the exit survey or if there was a log file showing a record of at least partial completion of the tutorial.

Utilization Tracking. Using the Toolbook Course Management System (SumTotal Corp.), we tracked all students' interactions with the computer. By having the students complete a brief log-in procedure, we were able to track the time and duration of the interaction, the titles of the screens accessed, and responses to multiple-choice questions embedded within the tutorials. At the end of each tutorial, the last screen was a multiple-choice question asking the student whether he or she had done the computer tutorial within a certain amount of time of seeing a patient with a condition relevant to the subject matter of the tutorial. This was meant to assess whether the students were using the tutorials in a just-in-time fashion to reinforce their case-based learning.

Because the students could navigate using a map function anywhere in the tutorial, we could not define tutorial completion as simply viewing all of the tutorial pages. Instead, we considered any interaction where the student covered 75% of the tutorial's screens and viewed the summary page as a tutorial completion. Tutorial interactions where the student spent less than 4 minutes or viewed fewer than five screens (trivial interactions) were not counted in the statistics. Pauses of more than 5 minutes were not counted in the estimates of time spent by the students on the tutorials.

Medical Student Surveys. We surveyed the students at three different times during their pediatrics rotation. At the time of the pretest, we asked them four questions about their computer experience; at the posttest, we asked which tutorials they had actually done and two questions about their clinical experience (whether or not they had read a cervical spine x-ray or glued a laceration, topics of two tutorials) as well as when they took their end-of-rotation written examination. This last survey was anonymous and solicited their attitudes toward several aspects of the computer tutorials. It was based on the Student Evaluation of Educational Quality, a well-known higher education student satisfaction survey.[25] We selected specific questions from the Student Evaluation of Educational Quality and minimally changed the wording to reflect our context. We pilot tested each of the surveys on one rotation block of students (n = 20), asking the students to comment on clarity and whether the intent of the questions was clear. We incorporated the suggested changes.

Faculty Survey. At the end of the study period, staff pediatricians were surveyed as to their attitudes toward the educational intervention. We included a stamped self-addressed postcard in the monthly mailing that included the physician schedule to all physicians doing shifts in the pediatric ED. The postcard listed five multiple-choice questions on the physicians' awareness of the tutorials and their attitudes toward them. These questions were developed ad hoc by the investigators and pilot tested on three physicians at a different institution. Suggestions were incorporated into a new draft of the survey and reflected back to the pilot testers. They did not suggest any further changes.

Data Analysis

We used descriptive statistics to summarize the results of our student and faculty surveys. Medians were used to summarize Likert-type questions, with interquartile ranges as the indicator of the variance in the point estimate. We summarized time estimates using means and 95% confidence intervals (CIs) where $\beta = 0.20$.

Sample Size. For the knowledge gain trial, we had information from previous examinations of the students where their average (±SD) score was 60% (±15%). Using a one-sample comparison of a mean to a hypothesized value of 70% (effect size of 0.67) where $\alpha = 0.05$ and $\beta = 0.20$, we estimated that we would require a sample size of 72 subjects divided equally between control and intervention groups. Given that in the actual trial we were able to use a within-groups design, we were confident of not making a type II error.

Marking of Examinations. We determined the intermarker correlations for examination scores using the intraclass correlation coefficient using a two-way mixed effect model where the people effect was random while the measure effect was fixed. We report the average measure intraclass correlation coefficient. We determined the reliability of the examination using Cronbach's α.

Knowledge Gain. We compared knowledge gain for students using two-way repeated-measures analysis of variance where the within-subjects factors were the time of test (pre vs. post) and tutorial exposure (yes vs. no). This was the main outcome for which the study was powered. In an exploratory fashion, we repeated the analyses successively substituting tutorial self-report of completion (yes vs. no) and tutorial log file present (yes vs. no) for tutorial exposure to determine the effect size when the tutorials were actually done by the students. Note that these latter analyses were done in a between-subjects fashion. We report the results in terms of means of raw scores as well as effect sizes (Cohen's *d*) with 95% CIs calculated using the ESCI software designed by Cumming and Finch.[26] The formula for Cohen's *d* is as follows:

$$\text{Cohen's } d = (\text{mean score}_{\text{intervention}} - \text{mean score}_{\text{control}}) / (\text{overall standard deviation})$$

Generally accepted interpretations of Cohen's *d* are as follows: small effect size, 0.2; medium effect size, 0.4; large effect size, 0.8.[27]

A priori we planned a subgroup analysis to compare examination scores for interactions where the students had done a given tutorial in a just-in-time fashion (i.e., within a shift where they saw a corresponding patient) with those of students who had done the tutorial without having recently seen a corresponding patient.

RESULTS

We carried out the study over a 14-month period from July 31, 2000, to September 22, 2001. During that time, 120 students were approached and agreed to participate.

Tutorial Use

We have usage tracking information from July 31, 2000, to June 21, 2001, when this feature was inadvertently turned off. There were 544 interactions by 95 different medical students with the computer over the study period (1.7 per day). In 222 of the interactions, the student did not complete the tutorial, defined as completing 75% of the screens and attaining the summary page. For the 322 interactions leading to tutorial completion, the median duration of the interaction was 11 minutes (mean [±SD], 14 [±12] minutes). This translates to more than 75 hours of instruction over 14 months.

The rate of tutorial completion decreased in direct proportion to the length of the tutorial, although the relationship was far from statistically significant (β coefficient = −0.38 [95% CI = −1.3 to 0.5; $n = 6$] for completion percentage regressed on number of screens in tutorial). We had time stamp data from 643 of the trainee (resident plus medical student) interactions. The majority of the interactions were during the day (289 [45%]) and evening (221 [34%]) shifts, but a surprising number occurred at night (133 [21%]). Moreover, night shift (midnight to 7:59 AM) interactions were more likely to result in completion (81/133 [61%]) than were day (138/209 [51%]) or evening interactions (112/221 [51%]). These differences are statistically significant overall (chi-square $p < 0.05$).

The tutorials were also used by other members of the ED community. Residents (156 interactions [20%]), other (56 [7%]), staff physicians (21 [3%]), and nurses (11 [1%]) all attempted the tutorials.

Knowledge Gain

A total of 120 students took the pretest, with 74 of these completing the posttest, allowing assessment of their knowledge gain. Figure 1 summarizes the number of students who completed the various components of the study. Students who completed the posttest did not differ significantly from noncompleters in their pretest scores (difference, 2%; t-test $p = 0.23$).

We have descriptive information for 117 of the students: 51 (44%) were female, 104 (89%) owned a computer, 99 (85%) could access the Internet at home, and 94 (80%) checked their e-mail daily. Asked to judge the statement "I learn well with a computer," 64 (55%) agreed or strongly agreed, while 11 (9%) disagreed or strongly disagreed. None of these factors differed between students who completed the posttest and those who did not.

Students attempted at least one tutorial to which they were randomized 89% of the time (66/74), while 54/74 (73%) did all three. Eight percent of the times when a student logged onto a tutorial, they did not complete it. Students self-reported or had a log file suggesting that they frequently logged onto a tutorial to which they were not randomized (65/222 possible) by signing in under the "resident" or "other" categories, which did not require specific log-in codes. All of these interactions were analyzed in the group to which they were randomized.

Intermarker correlations for the examination scores were good, with an average intraclass correlation coefficient of 0.88 (95% CI = 0.86 to 0.89). The scores of the marker with knowledge of the content of the tutorials did not differ from those of the other two; all three markers' scores were therefore used in the composite. The reliability of the six-item test was fair, with Cronbach's α of 0.48 for the pretest and 0.53 for the posttest. Dropping any one item did not make a material difference to the overall reliability.

The scores for the pretests and posttests are reported in Table 2. Overall, test scores improved from an average (±SD) of 2.9 (±1.9) out of 10 on the pretest to 4.9 (±2.4) on the posttest, which corresponds to a large statistically significant effect size for the rotation as a whole: Cohen's *d* of 1.9 (95% CI = 1.5 to 2.2).

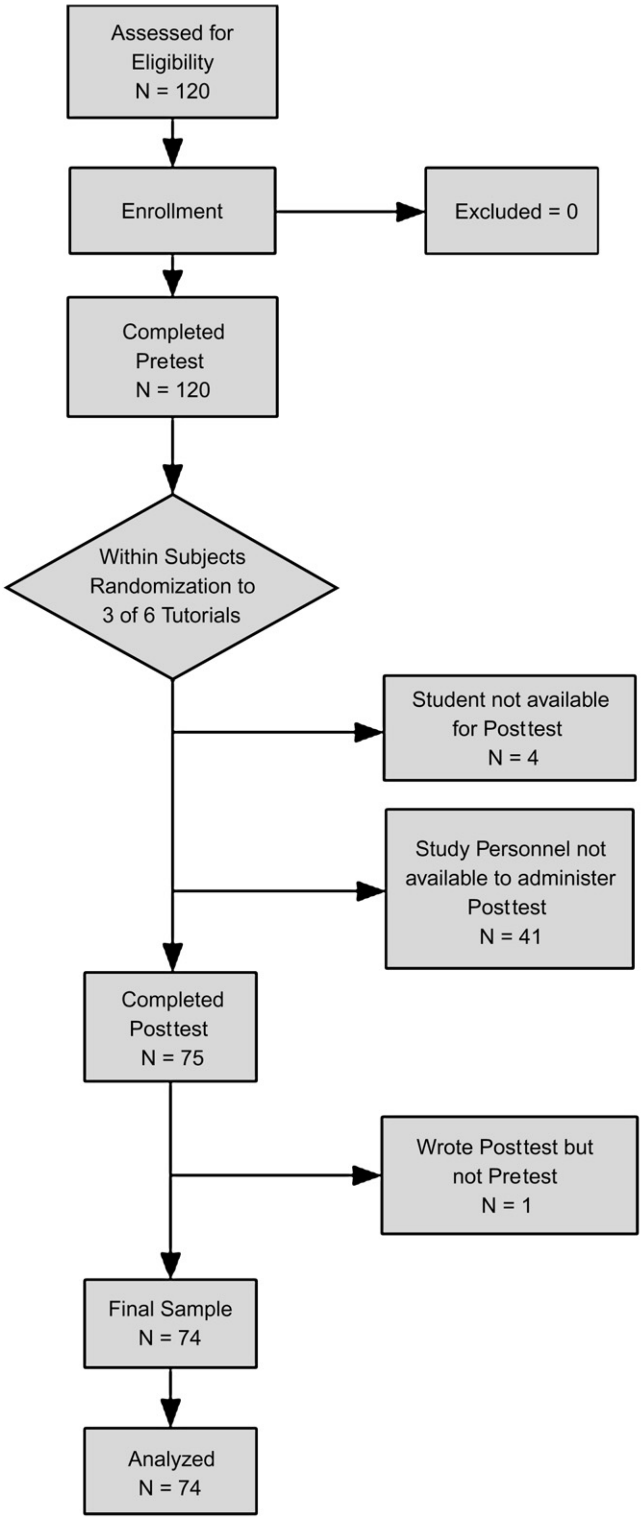

Figure 1. Study flow diagram showing the flow of medical students who entered the knowledge gain part of the study. Each student was randomly assigned three of the six available tutorials.

Main Knowledge Outcome Variable

For the 74 students who completed both tests, exposure to the tutorials resulted in a greater knowledge gain. For the three questions in the control condition, the students improved by 5.0 points out of 30 (16.7%); when exposed to the tutorials, they improved by 7.5 points (25%). This corresponds to a moderate effect size (Cohen's $d = 0.39$; 95% CI = 0.15 to 0.62). When we look at the tutorials that the students actually did, the effect was similar whether ascertained by log file ($d = 0.58$; 95% CI = 0.28 to 0.88) or student self-report on the exit survey ($d = 0.33$; 95% CI = 0.04 to 0.62). The log file analysis includes only student interactions during the period when logging was performed.

Considering the tutorials individually, for five of the six tutorials, there was at least a moderate effect size that ranged from 0.43 to 0.77 (see Table 2). The one topic where the computer tutorial made little difference ($d = 0.08$; 95% CI = −0.38 to 0.53) was the tutorial pictorially outlining the Salter–Harris Fracture Classification. This was the topic with the greatest knowledge gain overall from pretest to posttest. Both groups went from a score of <1 of 10 on the pretest to approximately 6 of 10 on the posttest, the highest score of all the topics.

Planned Subgroup Analysis

Our planned subgroup analysis examined whether doing the tutorials in a just-in-time fashion resulted in greater knowledge gain. There were 107 instances where the student completed the tutorial and there was information in the log file as to the timing of the tutorials with respect to patient cases. In the 16 instances where the tutorial was done within a shift where the student had seen a patient with the corresponding condition (compared with 91 where it was not), there was a moderate effect ($d = 0.47$), although it did not achieve statistical significance (95% CI = −0.07 to 1.00; power = 0.37) (Figure 2).

Exploratory Subgroup Analyses

On univariate analysis, the following factors were not associated with improved knowledge gain: gender, affinity for computers, computer ownership, and frequency of checking e-mail.

We asked the students whether they had 1) read a cervical spine x-ray and/or 2) used tissue adhesive to repair a laceration (each were topics of a tutorial). Students who had performed either of these tasks had increases in test scores that would be of practical significance. Students who had seen a cervical spine x-ray during the rotation had an effect size attributable to the tutorial of 0.20 (95% CI = −0.6 to 2.2) compared with 2.2 (95% CI = 1.4 to 2.9) for those who had not. Students who glued a laceration had an effect size attributable to the tutorial of 0.31 (95% CI = −0.6 to 1.2) compared with 0.6 (95% CI = −0.6 to 1.8) for those who had not. However, these interactions between the procedure and the tutorial were not statistically significant. The observed power for these comparisons is very low (power <0.20).

Student Survey

Of the 140 students available during seven rotation periods, 112 (80%) returned the survey soliciting their attitudes toward the computer tutorials and the rotation as a whole. For any given variable, there were between five and nine data points coded as missing. The results are reported in Figure 3, with student attitudes toward the tutorials largely positive. On the whole, the students did not find the tutorials "disruptive," although there was considerable variability on this question. The

Table 2
Results of Knowledge Gain Trial

Tutorial Subject	No. of Students Exposed to This Tutorial (N = 74)	No. of Students Who Completed the Tutorial (% of exposed)	Pretest Score (x out of 10 ± SD)		Posttest Score (x out of 10 ± SD)		Cohen's d: for Effect of Tutorial Compared with No Tutorial (95% CI)	p-value (t-test, df = 72)
			Not Exposed to Tutorial	Exposed	Not Exposed to Tutorial	Exposed		
Cervical spine x-rays	40	31 (78)	3.1 ± 1.5 (n = 34)	3.3 ± 1.2 (n = 40)	4.5 ± 1.4 (n = 34)	5.4 ± 1.9 (n = 40)	0.43 (−0.04, 0.89)	0.07
Febrile seizures	29	23 (79)	2.6 ± 2.0 (n = 45)	2.4 ± 1.5 (n = 29)	3.6 ± 2.1 (n = 45)	4.6 ± 2.1 (n = 29)	0.54 (0.06, 1.0)	0.03
Fever without source	47	33 (70)	4.4 ± 1.0 (n = 27)	4.3 ± 1.3 (n = 47)	4.3 ± 1.7 (n = 27)	5.3 ± 1.6 (n = 47)	0.61 (0.12, 1.1)	0.01
Growth plate fractures	36	17 (47)	0.8 ± 1.7 (n = 38)	1.0 ± 1.6 (n = 36)	5.9 ± 3.3 (n = 38)	6.4 ± 3.4 (n = 36)	0.08 (-0.38, 0.53)	0.75
Oral rehydration solutions	35	25 (71)	3.3 ± 1.7 (n = 39)	3.1 ± 1.3 (n = 35)	3.7 ± 2.1 (n = 39)	5.3 ± 2.1 (n = 35)	0.77 (0.1, 1.5)	0.001
Tissue adhesives	35	16 (47)	3.3 ± 1.7 (n = 39)	2.8 ± 1.9 (n = 35)	4.8 ± 2.1 (n = 39)	5.2 ± 2.0 (n = 35)	0.45 (0.01, 0.91)	0.06
Overall mean	**37 ± 6**	**24 ± 7 (65% ± 15%)**	**2.8 ± 2.0**	**2.9 ± 1.8**	**4.47 ± 2.3**	**5.39 ± 2.3**	**0.39 (0.15, 0.62)**	**0.001**
Overall mean irrespective of tutorials			**2.9 ± 1.9**		**4.92 ± 2.4**		**1.9 (1.5, 2.2)**	

students would have preferred a greater selection of tutorials beyond the six available. Of note, the students did not find the location of the tutorials, in the middle of a busy nursing station, to be problematic. Most students agreed with the statement that the tutorials should be done soon after seeing a patient with a relevant condition.

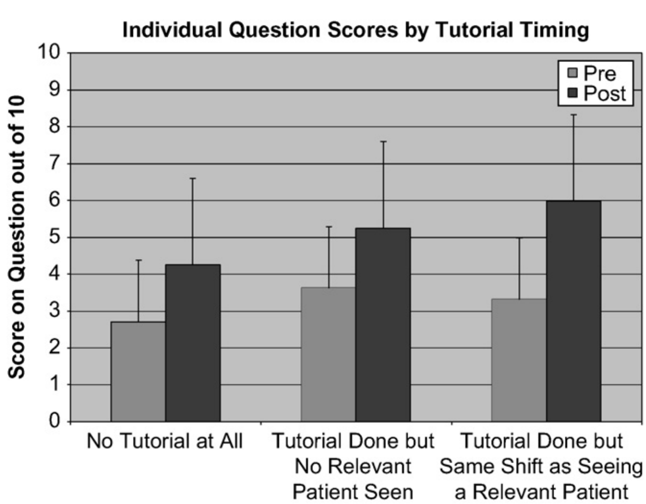

Figure 2. Individual question scores by tutorial timing. This shows how pretest to posttest increases in mean scores are affected by whether the tutorial is done in concert with seeing a relevant patient. The histograms on the left show the gain for students in the control condition (did not do a tutorial but may have seen a relevant patient). The histograms in the middle show the scores of students who did a computer tutorial but did not see a patient relevant to the given tutorial within the concurrent eight-hour emergency department shift. The histograms on the right show the knowledge gain for students who did a tutorial within eight hours of seeing a relevant patient. This was a planned subgroup analysis. The difference between these two latter groups is not statistically significant ($p = 0.10$; $\beta = 0.37$).

When asked to attribute their learning (excluding learning at the bedside from their patients), the 99 students who replied to the question believed they learned the most from their preceptors in the pediatric ED (32% ± 17%) and their own reading (42% ± 19%), compared with the scheduled small group learning sessions (14% ± 11%) or the computer tutorials (11% ± 7%). Interestingly, 54% of the students ranked the computer tutorials higher than the small group teaching sessions (Wilcoxon; p = 0.05), while only a minority preferred them to the pediatric emergency medicine preceptors (19%) or their own reading (10%).

Faculty Survey

We distributed 59 faculty surveys and had 37 returned (63%). Asked whether they were aware of the tutorials being in the department, the majority (70%) responded affirmatively. However, relatively few had looked at the content of the tutorials, with 20% having seen more than one, 26% one, and 54% none of the six tutorials. Only one of the respondents had seen all six tutorials. We asked whether the faculty respondents had ever directed the students to do the tutorials. Most responded that they either never (50.4%) or rarely (22%) did so; however, 11% responded that they directed students to the tutorials on "most" shifts. Asked whether they believed that having the students do the tutorials during their shifts was disruptive, the majority either strongly disagreed (20%) or disagreed (51%), although a substantial minority (28%) did indeed think they might be disruptive. Finally, we asked the faculty to speculate on whether it was better for the students to do the tutorials "right after" a patient encounter versus on their free time. A

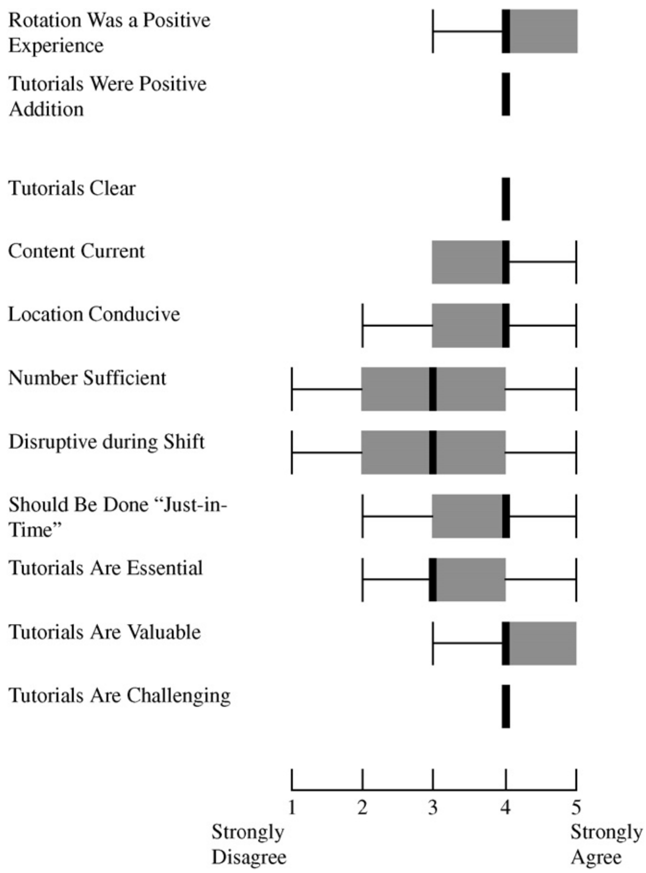

Figure 3. **Students' attitudes toward tutorials and rotation. The results of a satisfaction survey of students at the end of their pediatrics rotation are shown. The darkest middle line is the median response, and the gray box represents the interquartile range. Whiskers are the 5% and 95% percentiles.**

sizeable majority believed that coupling the tutorial with a patient encounter would be preferable (strongly agree, 27%; agree, 44%).

DISCUSSION

We have demonstrated that the use of brief, focused computer tutorials for medical student learning is feasible within a busy clinical setting. CAI has been used in a wide variety of clinical settings, including primary care clerkships,[28] outpatient rotations,[2] and EDs.[24,29] Recent meta-analyses have shown that, for medical trainees, CAI is effective.[8,30–32] However, comparatively few of these interventions were performed directly in a clinical setting where the trainee is charged with seeing patients.

Cook et al. developed Web-based modules on common conditions encountered in an internal medicine resident continuity clinic.[2] They compared this intervention with a paper-format evidence-based guideline for each topic using a randomized crossover design. Each resident completed two topics using paper and two using the Web-based intervention over a one-year period. The main outcome was resident format preference, with 78% of 73 students preferring the Web format compared with 16% who preferred the print version. There was no difference in effect size (approximately 0.66 for each group). Several of their subjects suggested that time should be set aside specifically for doing the tutorials. There is no documentation of how much the residents learned on these topics from their patients.

Kerfoot et al. added a Web-based teaching component to a medical student urology rotation at four medical schools.[30] Using a randomized-block design similar to ours, they randomized 351 students, with 210 eventually completing the Web tutorials and the pretest and posttest. The intervention consisted of text-based Web tutorials on two topics; the control condition was two topics for which the students did not receive any supplemental teaching. They demonstrated an outstanding effect of the tutorials with an effect size of 1.52. However, again it is not clear how the tutorials leveraged clinical learning; on each of the four topics tested, the students learned comparatively little from the rotation itself.

What is not clear from the studies by Cook et al. and Kerfoot et al., or similar studies, is how the learning from the computer tutorials interacts with the learning from the clinical experiences of the trainees. We sought to embed tutorials right into the students' day-to-day clinical experience to take best advantage of clinical context (situating the learning), the computer tutorials (multimedia learning), and the interaction between the two (just-in-time learning).

We believe that the single most important finding of this study was that medical students on rotation in a busy clinical setting could and would do the computer tutorials. The tutorials were not mandatory. Our faculty did not, despite our encouragement, directly instruct the students to do the tutorials. Nonetheless, 89% of students did at least one tutorial, while 73% did all three assigned to them. In addition, a significant percentage did extra tutorials. Over a 14-month period, the tutorials delivered at least 75 hours of direct instruction, much of it during off-hours. Our anecdotal experience was that the students did the tutorials at slow times in the ED when there were no patients to be seen. The fact that the computer was in a busy, highly visible area of the ED did not hamper the students' willingness to use it.

The tutorials were effective in increasing examination scores. When students had a tutorial available to them, they scored one third higher on that question compared with the control condition. This corresponds to an effect size of 0.39, which is moderate by Cohen's guidelines.[27] This estimate is likely a conservative measure of the potential effect of embedding tutorials in a clinical setting. Contamination of the control group with tutorial knowledge occurred in at least 25% of interactions. Also, the low reliability of our examination would increase the noise in the data, resulting in effect size estimates biased downward. Even though the real estimate is likely higher, an effect size of 0.39 is educationally important. For perspective, the average effect size attributable to CAI in large meta-analyses in a variety of settings is approximately 0.42.[7]

It can be argued that this effect is the result of the computer tutorials shifting the educational agenda of the students as opposed to necessarily increasing their learning. If the tutorials had not been there, the students might have learned the same amount from the rotation as a whole, just not as much on the six particular topics for which there was a tutorial. We argue that this ability to set the educational agenda within a clinical rotation is a powerful tool for the medical educator.[15] In addition, if the topics and instructional strategies of the tutorials are carefully chosen, the tutorials have the potential to increase learning compared with what the students would have been doing otherwise. Using a just-in-time approach to maximize the advantages of knowledge relevance, applicability, and timeliness can be done by anticipating the needs of learners within their working and learning settings and managing the content for the purposes of optimal computer and human interplay.[20,33]

There are many ways in which we could increase the impact of the computer tutorials. The most obvious is to increase faculty awareness of the tutorials and their content. Our faculty members were largely unaware of the content of the tutorials, with the vast majority having seen one tutorial of the six. They referred students to the tutorials only rarely. A faculty development program that centered on incorporating the tutorials into clinical teaching could have the advantage of increasing the use of the tutorials and of raising the level of the faculty–student interchange by including the often-superior visual material of the tutorials.[32]

We believe that students would be more likely to do the tutorials if the faculty explicitly endorsed them on a day-to-day basis. One option is to make the tutorials a mandatory part of the curriculum in the same way that lectures or small group sessions are. We would need to seek a careful balance between allowing the students to use the tutorials in an a la carte manner that allows them to pursue their own learning needs and explicitly mandating activities that the students may have covered in a different but equally valid manner.

An example of this tension is our experience with the growth plate fractures tutorial. Going into the study, this was one of the tutorials with which we were most pleased. Using computer graphics and animations, it visually explained how to categorize growth plate fractures according to the Salter–Harris classification and discussed prognosis and management. However, in the trial, this tutorial, to our surprise, was the least effective, with an effect size of essentially zero, compared with approximately 0.7 for the other tutorials. What we think happened is that we did not take into account the dedication of our surgical ED faculty in teaching this concept. It would be rare for a student to leave a shift in the surgical part of the ED without the preceptor having explained the concept to the student, complete with drawings scrawled on the back of an x-ray envelope. The students went from pretest scores of zero to very high scores, even in the control condition. There was simply no educational room left for our tutorial to exploit. The students recognized this when they made choices as to which educational activity to pursue. For students randomized to the growth plate tutorial, fewer than half actually did the tutorial, compared with >70% for most of the other tutorials.

This example points to a larger truth about the use of computer tutorials to supplement learning in a clinical setting. We have shown that they can be effective and that students are willing and able to do them while on clinical duty. However, like others, we believe the best use of these tutorials will be determined by the local context, which includes taking into account what is best learned from patients and preceptors and then explicitly choosing computer tutorial content and instructional strategies that best fill in the gaps that remain.[1,34]

LIMITATIONS

We had some technical problems while conducting the study. Not all students who took the pretest completed the posttest due to a miscommunication between study personnel. The effect of this on our main outcome variable is mitigated by the within-subjects design of the study. For our between-subjects comparisons, there is no reason why this random event would be expected to result in a systematic difference between the completers and noncompleters. This could affect the generalizability of the results in that we did not consecutively sample all students in a medical school class. All measured outcomes were analyzed in the groups to which they were randomized regardless of whether they did the tutorials or not.

This is essentially a "black-box" evaluation in which we have shown that our intervention can be effective, but we have not directly shown which specific features of the tutorials lead to the positive benefits. There may be specific instructional designs within the tutorials that lead to the benefits, but we can only speculate as to which features were most helpful.

The quantitative estimate of the effect of the tutorials was almost certainly diminished by contamination, wherein the positive effect of the intervention spilled over to the control condition.[35] In this case, we know that for >25% of the interactions, the subjects actually did tutorials to which they had not been randomized. In addition, it is likely that the students talked about the content of the tutorials or may have shown each other the tutorials while on shift together. We could have designed a tighter log-in system to lock the students into their assigned condition. However, the students were implicitly endorsing the tutorials by effectively saying that seeing the content of the tutorials was important to them.

Another limitation of our findings is that the subgroup analyses are underpowered to exclude the possibility of a type II error. It will be interesting to design studies to explicitly examine the interaction of these brief computer tutorials with actual clinical experience. For example, we have hints that, at least for knowledge examinations, the computer tutorials may lead to even greater learning if done in conjunction with seeing a relevant case or performing a relevant procedure. However, in the absence of random assignment and sufficient power, we can only use these findings for hypothesis generation.

We need to verify that the tutorials are not replacing potentially more important learning from preceptors or patients. Doing computer tutorials instead of seeing patients is clearly an unacceptable trade-off. Our patient tracking system and our study design were not capable of ensuring that the number of patients seen by the students did not decrease because of the time taken to complete the tutorials. We counted on the social pressure of having the computer station in the busiest part of the nursing station to ensure that it was used in a responsible manner. Other limitations include the lack of a test of retention over an extended period and the use of instruments that have not been fully validated.

CONCLUSIONS

In this study, we showed that medical students can and will do computer tutorials presented on a station embedded in the heart of a busy ED. Our tutorials were explicitly designed to be brief, focused, and relevant and to use computerized instructional strategies to best advantage. Using a randomized controlled trial, we demonstrated that exposure to the tutorials can significantly improve knowledge outcomes. In addition, surveys of both students and faculty showed positive attitudes toward the tutorials, although their importance relative to bedside learning should not be overstated. There is considerable potential to refine the technique by optimizing the timing of tutorial delivery, the degree of preceptor involvement, and the choice of content and instructional strategy.

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References

1. Ruiz JG, Mintzer MJ, Leipzig RM. The impact of e-learning in medical education. Acad Med. 2006; 81:207–12.
2. Cook DA, Dupras DM, Thompson WG, Pankratz VS. Web-based learning in residents' continuity clinics: a randomized, controlled trial. Acad Med. 2005; 80: 90–7.
3. Osman LM, Muir AL. Computer skills and attitudes to computer-aided learning among medical students. Med Educ. 1994; 28:381–5.
4. Wilkes M. Changing clinical practice [comment]. Med Educ. 2001; 35:924.
5. Williams C, Aubin S, Harkin P, Cottrell D. A randomized, controlled, single-blind trial of teaching provided by a computer-based multimedia package versus lecture. Med Educ. 2001; 35:847–54.
6. Friedman CP. The research we should be doing. Acad Med. 1994; 69:455–7.
7. Kulik C-LC, Kulik JA. Effectiveness of computer-based instruction: an updated analysis. Comput Hum Behav. 1991; 7:75–94.
8. Chumley-Jones HS, Dobbie A, Alford CL. Web-based learning: sound educational method or hype? A review of the evaluation literature. Acad Med. 2002; 77(Suppl):S86–93.
9. Lave J, Wenger E. Situated Learning: Legitimate Peripheral Participation. Cambridge, England: Cambridge University Press, 1991.
10. Brown JS, Collins A, Duguid P. Situated cognition and the culture of learning. Educ Res. 1989; 18(1):32–42.
11. Anderson JR, Reder LM, Simon HA. Situated learning and education. Educ Res. 1996; 25(4):5–11.
12. Tripp SD. Theories, traditions, and situated learning. Educ Tech. 1993; 33(3):71–7.
13. Herrington J, Oliver R. An instructional design framework for authentic learning environments. Educ Tech Res Dev. 2000; 48(3):23–48.
14. Young M. Instructional design for situated learning. Educ Tech Res Dev. 1993; 41(1):43–58.
15. Valcke M, De Wever B. Information and communication technologies in higher education: evidence-based practices in medical education. Med Teach. 2006; 28:40–8.
16. Mayer RE. Multimedia Learning. Cambridge, England: Cambridge University Press, 2001.
17. Jonassen D. Design of constructivist learning environments. In: Reigeluth C, ed. Instructional-Design Theories and Models: A New Paradigm of Instructional Theory. Volume 2. Mahwah, NJ: Lawrence Erlbaum & Associates, 1998, pp. 215–39.
18. Davies ML, Crowther DEA. The benefits of using multimedia in higher education: myths and realities. Active Learn. 1995; 3(4):3–6.
19. Beckett D, Agashae Z, Oliver V. Just-in-time training: techne meets phronesis. J Workplace Learn. 2002; 14: 332–9.
20. Weintraub RS, Martineau JW. The just-in-time imperative: the imperative—and the problems—tracking trends. T+D. 2002; 56(6):50–8.
21. McLellan H. "Being digital": implications for education. Educ Tech. 1996; 36(6):5–20.
22. Chueh H, Barnett GO. "Just-in-time" clinical information. Acad Med. 1997; 72:512–7.
23. Krauss BS, Harakal T, Fleisher GR. The spectrum and frequency of illness presenting to a pediatric emergency department. Pediatr Emerg Care. 1991; 7: 67–71.
24. Pusic M, Johnson K, Duggan A. Utilization of a pediatric emergency department education computer. Arch Pediatr Adolesc Med. 2001; 155:129–34.
25. Marsh HW. SEEQ: a reliable, valid, and useful instrument for collecting students' evaluations of university teaching. Br J Educ Psychol. 1982; 52: 77–95.
26. Cumming G, Finch S. A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. Educ Psychol Meas. 2001; 61:532–74.
27. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Mahwah, NJ: Lawrence Erlbaum Associates, 1988.
28. Sakowski HA, Rich EC, Turner PD. Web-based case simulations for a primary care clerkship. Acad Med. 2001; 76:547.
29. Baumlin KM, Bessette MJ, Lewis C, Richardson LD. EMCyberSchool: an evaluation of computer-assisted instruction on the Internet. Acad Emerg Med. 2000: 7:959–62.
30. Kerfoot BP, Baker H, Jackson TL, et al. A multi-institutional randomized controlled trial of adjuvant Web-based teaching to medical students. Acad Med. 2006; 81:224–30.
31. Letterie GS. Medical education as a science: the quality of evidence for computer-assisted instruction. Am J Obstet Gynecol. 2003; 188:849–53.

32. Greenhalgh T. Computer assisted learning in undergraduate medical education. BMJ. 2001; 322: 40–4.
33. Bandiera G, Lee S, Tiberius R. Creating effective learning in today's emergency departments: how accomplished teachers get it done. Ann Emerg Med. 2005; 45:253–61.
34. Cook DA. The research we still are not doing: an agenda for the study of computer-based learning. Acad Med. 2005; 80:541–8.
35. Chuang J, Hripcsak G, Heitjan D. Design and analysis of controlled trials in naturally clustered environments: implications for medical informatics. J Am Med Inform Assoc. 2002; 9:230–8.