

Medical Informatics

An Interactive Web-based Curriculum on Evidence-based Medicine: Design and Effectiveness

Katherine Schilling, EdD; John Wiecha, MD, MPH;
Deepika Polineni, MD, MPH; Souad Khalil, MS

Background and Objectives: Medical education experts have called for improved training in evidence-based medicine (EBM) and the increased use of e-learning technologies in medical education. In response, we developed an interactive, Web-based curriculum on key aspects of EBM in family medicine. **Methods:** Students participating in a 6-week family medicine clerkship (n=238) were randomly assigned to intervention (n=134) or control (n=104) groups. Both groups participated in the traditional clerkship experience, but intervention group students received additional training via an on-line curriculum that included learning modules in MEDLINE searching skills, EBM skills, and the calculation of the number needed to treat (NNT) statistic. The on-line curriculum was evaluated using a case-control design with a test case at the clerkship's end. **Results:** Results suggested that the on-line curriculum was effective, with experimental group students outperforming control group participants on a variety of measures, including the number of MEDLINE searches conducted during the clerkship (13 searches versus 3 searches) and the quality of literature search strategies on an evaluation patient case study (2.9 versus 2.1 on a 1=poor to 4=excellent scale). Intervention group students reported greater confidence and enjoyment in searching the biomedical journal literature via MEDLINE and were more likely to identify the best articles (randomized controlled trials or meta-analyses) for the evaluation case from among those retrieved (60% versus 34%). In addition, intervention group students' abilities to correctly calculate the NNT were significantly higher than those of control group participants (73% versus 27%). Intervention group students were more likely than control subjects to report learning from other students during the clerkship. **Conclusions:** This study demonstrates that an e-learning approach to educating medical students to effectively search MEDLINE for articles meeting the criteria for evidence-based practice can result in higher-quality literature search strategies, identification of higher-quality evidence, and improved confidence in information retrieval and analysis skills.

(Fam Med 2006;38(2):126-32.)

Evidence-based medicine (EBM) is "the conscientious, explicit, and judicious use of the best evidence in making decisions about the care of individual patients."¹ The practice of EBM requires that clinicians acquire expertise in locating, evaluating, and applying appropriate high-quality medical information to a clinical problem or question. In response to national education and accreditation standards in support of EBM, most US medical schools and residency programs include some form of EBM training.²⁻⁴ EBM skills are taught

in a variety of ways, including implementing separate courses, merging EBM skills training into existing required or elective courses, or integrating EBM longitudinally throughout the curriculum.^{1,5} Despite this increased focus on evidence-based practice and training, few studies have described the importance of effective MEDLINE searching skills for retrieving and identifying relevant biomedical journal literature.^{6,7} In addition, no studies have reported evaluating the effectiveness of providing EBM training to learners at remote sites via e-learning and distance education technologies.

In third- and fourth-year courses that are held in off-campus, community-based clinical sites, students and faculty are often physically remote from the academic medical center. Despite the benefits of these community

From the School of Library and Information Science, Indiana University (Dr Schilling); Department of Family Medicine, Boston University (Dr Wiecha); and Department of Internal Medicine, University of Michigan (Mr Polineni).

placements, medical students who work off campus have less interaction and fewer learning opportunities with peers and core faculty and may experience inadequate access to conventionally structured curricular content.⁸

In response to the need to standardize learning across multiple clinical sites, create a community environment for geographically disbursed learners and faculty, and provide opportunities for students to learn about and practice EBM, the Boston University Department of Family Medicine developed an on-line distance education curriculum to augment its family medicine clerkship. The on-line clerkship is delivered on Blackboard's CourseInfo[®] software via an interactive, Web-based learning tool. This paper describes the development, teaching, and evaluation of the EBM component of the on-line course. Although the course was created for third-year medical students enrolled in a clinical clerkship, the content and instructional design are relevant to a broad spectrum of learners in medical education.

Methods

This randomized, blinded study examined how and to what extent the implementation of an interactive, on-line curriculum in a family medicine clerkship impacted on clerks' information retrieval skills, EBM practice skills, and perceptions about the clerkship experience. Research methods and data sources were approved by the university's Institutional Review Board.

On-line Family Medicine Clerkship Curriculum

The Department of Family Medicine on-line clerkship EBM curriculum was designed with three core goals: (1) to promote the effective retrieval of biomedical journal literature via the OVID[®] MEDLINE system, (2) to increase students' awareness and use of relevant clinical guidelines, and (3) to teach the calculation and interpretation of a fundamental EBM metric from clinical trial data: the number needed to treat (NNT) statistic.⁹ NNT is a measure of practical clinical utility of therapeutic and screening interventions calculated from clinical trials describing how many patients must be treated to benefit one patient.

The on-line course design was guided by educational psychology principles, including adult learning concepts and the utility of reflective learning and collaborative or peer-driven learning.^{10,11} Although a number of EBM instructional resources were already available on the Internet, our family medicine on-line curriculum was unique in that it was designed to follow a deliberate sequence of educational activities, to promote reflection and interaction among students and faculty, and to require learners to apply EBM concepts from the on-line course to real patient encounters.

During the first and second weeks of the clerkship, respectively, students used two course-integrated, Web-based learning modules about MEDLINE and EBM database information retrieval skills. The modules were created specifically for the on-line clerkship by academic health sciences reference librarians, with input from clinical faculty and an educational media specialist. The content required 40 to 60 minutes to complete and was anchored in information literacy competency standards for higher education and on widely accepted information retrieval process models.¹²⁻¹⁴ Although students were required to complete the curriculum and assessments, their searching performance on the final EBM case was not included in their clerkship grade.

The first literature searching tutorial was designed to refresh students' basic MEDLINE searching skills, teaching them to identify Medical Subject Headings (MeSH) to represent the concepts being searched, appropriately apply searching functions such as the MeSH "explode" or "focus" commands, use subheadings, and combine terms with Boolean operators. The second searching tutorial was more advanced, teaching more-sophisticated searching functions and effective strategies for retrieving randomized controlled trials (RCTs), meta-analyses, and the "gold standard" literature. This tutorial presented tactics for searching the Cochrane databases and other EBM resources and taught students about different types of research and the kinds of information presented in each (such as cohort studies, meta-analyses, and RCTs).

During week 4, clerkship students were introduced to the National Guideline Clearinghouse (www.guideline.gov/) from the US Department of Health and Human Services, Agency for Healthcare Research and Quality (AHRQ). In week 5, the Michigan State University Department of Family Practice's "Introduction to Information Mastery" tutorial (www.poems.msu.edu/InfoMastery/) showed students how to calculate and interpret the NNT statistic. Students then applied each of these on-line lessons to a real patient encounter and described their clinical question, search process, and findings in an asynchronous discussion board moderated by faculty.

Evaluation

Data were gathered from several sources, including (1) a pre-clerkship survey (self-reported), (2) analysis of students' MEDLINE literature search strategies (measured), (3) analysis of retrieved articles identified by students as providing the best evidence to address a clinical case study (measured), (4) a post-clerkship survey (self-reported), and (5) a post-clerkship NNT test (self-reported). These data were gathered from third-year medical students participating in the Boston

University Department of Family Medicine clerkship during a continuous 21-month period.

Alternating blocks of clerks were assigned to the intervention group. Control group students (n=104) participated in a traditionally structured clerkship without the supplemental on-line EBM curriculum, while intervention block students (n=134) participated in a clinical clerkship that included the implementation of the on-line EBM content.

Clerks completed a pre-clerkship survey that recorded baseline demographic data and students' perceptions regarding their clinical skills, knowledge of MEDLINE searching functions, and understanding of EBM concepts and methodologies. Post-clerkship surveys included questions that mirrored those of the pre-clerkship survey and allowed students to describe their information usage behaviors and EBM skills and evaluate the clerkship.

During the final (sixth) week of the clerkship, students completed a clinical case problem of a middle-aged male patient who inquired about the use of aspirin for the primary prevention of heart disease. Students were asked to formulate a clinical question and perform a literature search. Before entering the clerkship, all students were assigned individual accounts on the university's OVID MEDLINE system. Search activity was electronically captured, blinded, and independently evaluated by three reference librarians, allowing for a comprehensive analysis of each student's literature searching skills. MEDLINE searches were scored on a scale of 1 (poor) to 4 (excellent), based on students' abilities to formulate a clinical question, develop an effective search strategy, identify and appropriately manipulate correct MeSH terms, successfully apply Boolean operators, restrict search results to randomized controlled trials or meta-analyses, and utilize OVID MEDLINE's features and functions, including the application of specific, appropriate "limit" qualifiers. These evaluation criteria were established in previous research on third- and fourth-year medical students' MEDLINE searching strategies.¹⁵⁻¹⁷

The reference librarians were trained in MEDLINE search evaluation techniques and were provided with standardized variables and criteria on which to evaluate each search strategy. Inter-rater reliability was assessed via statistical tests. The resulting correlation coefficients ranged from 0.66 ($R^2=0.43$) to 0.81 ($R^2=0.65$), showing that a good relationship existed between librarians' scoring patterns.¹⁸

In addition to performing the literature search, students were instructed to review their search results and identify the two articles that best addressed the clinical question and represented the threshold for providing the best evidence. These data were blinded and evaluated by two clinical faculty on a scale of 1 (poor) to 4 (excellent). The 4 (excellent) rating was assigned to primary

prevention RCTs or meta-analyses of these trials; a 3 (good) rating was assigned to cohort studies, review articles, and articles reporting sub-analyses; marginal (2 rating) studies were those reporting only data on women, those that did not clearly provide evidence, or studies with other atherosclerosis-related outcomes; and a rating of 1 (poor) was assigned to all other articles. Differences in proportions were tested using the chi-square statistic, and differences in continuous variables were evaluated using *t* tests.

Results

The final EBM case was completed by 85.5% of clerkship students in the blocks that administered the case, with comparable response rates for other outcomes. Data related to the demographic composition of control and intervention groups were gathered and compared. There were no statically significant differences between the groups for variables, including students' ages (mean 27 years in both groups), race/ethnicity (50% white, 33% Asian, and the remainder about 5% each of black, Hispanic, or other), and gender (33% female), MCAT scores, grade-point averages, computing skills, computer usage patterns, and Web access ($P>.05$ for all).

When three independent scores for each student's literature search were averaged to create one mean score for each student, the average score among all students was 2.5 on the 1 (poor) to 4 (excellent) scale. The scores for intervention group students and control group students were then averaged to create one mean score for each training group. Intervention group students achieved a mean MEDLINE searching score of 2.9, and control group students achieved a mean score of 2.1 ($P<.05$), indicating that intervention (on-line clerkship) students performed more-effective literature searches than did their control group counterparts and providing evidence that the on-line curriculum was an effective intervention for improving third-year medical students' searching skills (Table 1).

The research also sought to identify differences between experimental groups in terms of their abilities to identify high-quality articles (RCTs and meta-analyses) from among those retrieved. Results showed that intervention group students selected higher-quality articles than did control group students. Sixty percent of those in the intervention group selected either an RCT or meta-analysis as providing the best evidence, while only 34% of control group students selected an RCT or meta-analysis (Table 1). MEDLINE searching scores correlated with the quality of selected articles ($P=.01$). Among those students who achieved a 4 or "excellent" score for their article selections, the mean MEDLINE search quality score was 3.2, (or "good" on the parallel 1-4 scale). Students who achieved a 3 ("good") score for article selections had a mean search quality score

Table 1
Major Measured Outcomes of the On-line EBM Curriculum

<i>OUTCOME</i>	<i>CONTROL</i>		<i>INTERVENTION</i>		<i>OR (95% CI)</i>	<i>P Value</i>
	<i>Result</i>	<i>n*</i>	<i>Result</i>	<i>n*</i>		
<i>Performance Outcomes</i>						
Mean librarian search process rating**	2.1	58	2.9	74	—	<.05
Student retrieved and selected highest-quality evidence for case study	21 (33.9%)	62	55 (59.8%)	92	2.9 (1.4, 6.0)	<.01
NNT correctly calculated	20 (22.2%)	90	54 (60.7%)	89	5.4 (2.7, 11.0)	<.05
Mean number of MEDLINE searches during clerkship (measured)	2.6	105	12.4	112	—	<.05
Mean number of searches using Cochrane database during clerkship (self-reported)	0.2	105	1.6	112	—	<.05
Preference for search program at clerkship end:						<.05
OVID	58.3%	67	77.2%	78		
PubMed	7.0%	8	4.0%	4		
None	32.2%	37	16.8%	17		
Other	2.6%	3	2.0%	2		

EBM—evidence-based medicine

NNT—number needed to treat

OR—odds ratio

* Sample sizes vary since some clerkship blocks were not administered all instruments.

** Quality of articles rated as excellent (4 points), good (3 points), fair (2 points), or poor (1 point).

of 2.7 (a high “fair”) whereas students whose article selections scored 2 (“marginal”) or 1 (“poor”) received significantly lower MEDLINE searching scores (mean score=2.4).

To determine the effect of the intervention on students’ searching behaviors, OVID database searches were electronically captured and blinded starting at the beginning of the clerkship. Intervention group students performed an average of 12 searches over the 6-week clerkship, whereas control group students performed an average of three searches during the same time period ($P<.05$).

Surveys also asked respondents to indicate their MEDLINE system preferences, choosing between OVID MEDLINE, PubMed, or other systems. At clerkship end, intervention group students reported preferring OVID MEDLINE over other MEDLINE systems at a substantially higher rate than did the control group students (Table 1).

During the final week of the family medicine clerkship, students calculated an NNT from a hypothetical clinical trial. Substantially more intervention group

students than control group students were able to correctly calculate this number (Table 1).

Pre- and post-clerkship survey question pairs recorded respondents’ attitudes about their literature searching skills and their satisfaction with the search process and results. All were Likert scale questions with the lowest rating coded as 1 or “strongly disagree” and the highest rating coded as 5 or “strongly agree.” The results revealed significant differences between training groups for all questions. Intervention group students were more confident in their skills and were more likely to agree that they knew how to perform a literature search for evidence and locate relevant clinical guidelines. These data are displayed in Table 2.

An attachment to the post-clerkship survey administered only to on-line blocks gauged students’ perceptions of the quality and efficacy of the on-line family medicine clerkship. While not all students agreed that they enjoyed the on-line curriculum, they did report being generally satisfied with its content, agreeing that it was easy to use and had improved their information retrieval skills. Students also agreed that their clinical

Table 2
Self-reported Outcomes of the On-line EBM Curriculum

	<i>CONTROL GROUP</i> <i>n=103</i>		<i>INTERVENTION GROUP</i> <i>n=94</i>		<i>Difference in Change**</i>	<i>P Value for Difference in Change</i>
	<i>Before Clerkship (a)</i>	<i>After Clerkship (b)</i>	<i>Before Clerkship (c)</i>	<i>After Clerkship (d)</i>		
<i>Attitude Outcomes*</i>						
I know how to conduct an EBM search.	4.0	4.2	3.6	4.6	+0.8	<.05
Searching OVID MEDLINE is easy for me.	4.0	3.9	3.8	4.3	+0.6	<.05
I know how to form clinical questions to answer with MEDLINE	3.3	3.6	3.1	3.8	+0.4	<.01
My use of MEDLINE always yields the most relevant citations.	3.2	3.3	3.2	3.6	+0.3	.07
Using the library's OVID MEDLINE system is enjoyable.	3.0	3.0	2.7	3.1	+0.4	<.05
I know how to locate useful clinical guidelines and protocols.	2.8	3.3	2.6	3.7	+0.6	<.001
This clerkship improved my ability to practice EBM.	—	3.4	—	4.2	+0.8	<.001
During this clerkship I learned from other BU clerkship students.	—	2.9	—	3.4	+0.5	<.01

EBM—evidence-based medicine
BU—Boston University

* Agreement with each statement was measured before and after the clerkship with a 5-point Likert Scale (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree).

** Calculated as (d-c) - (b-a). A "difference in change" of +1.0 would indicate that, from before to after, the on-line group increased by 1 point more than the comparison group on the Likert scale.

preceptors were supportive of their participation in the course and that the on-line interaction among faculty and students was valuable. On-line students were more likely than control subjects to report learning from other students during the clerkship. Results from these and related questions are shown in Table 3.

Discussion

Clerkship evaluation results show that an e-learning curriculum can improve students' information retrieval skills, increase the likelihood of identifying the best available evidence for guiding patient management, and promote the practice of EBM. Although prior research has shown that students' literature searches generally retrieve a small percentage of relevant articles on any given clinical topic,¹⁹ students completing the on-line curriculum demonstrated superior performance over control students in this key outcome area.

Since the completion of this experiment, the on-line curriculum has been implemented for all students participating in the third-year family medicine clerkship and is being reviewed as a model for programs in other departments and clinical rotations. Future enhancements to the on-line clerkship are planned, including more-robust components addressing critical appraisal and increased feedback on students' individual MEDLINE literature-searching strategies and skills. We are also looking into modifications to improve course satisfaction ratings.

Future studies should include assessment of the influence of information retrieval training on students' longer-term search skills. Durability of skills is generally better among programs using a longitudinal educational design rather than episodic models.^{20,21} Further research is also warranted on how students interpret and apply the biomedical journal literature to real patients, and the subsequent impact on patient care outcomes.^{7,19}

Table 3

Post-clerkship Attitudes of Students Who Completed the On-line EBM Curriculum

Question	% Agree	n	% Disagree	n	% Neutral	n
The basic OVID MEDLINE tutorial improved my ability to retrieve useful citations.	69.7%	92	15.9%	21	14.4%	19
The EBM searching tutorial equipped me with the skills to use these resources effectively.	55.4%	72	16.2%	21	28.5%	37
The required literature searches improved my EBM skills.	64.7%	86	15.8%	21	19.6%	26
The Clinical Guidelines tutorial improved my ability to locate and evaluate relevant guidelines.	53.0 %	70	15.9%	21	31.1%	41
I enjoyed the on-line clerkship.	38.4%	51	36.8%	49	24.8%	33
The on-line content was easy to use.	59.2%	77	17.7%	23	23.1%	30
The on-line clerkship improved my ability to practice EBM.	66.9%	89	18.8%	25	14.3%	19
After completing the clerkship, I am now more likely to do an EBM search to answer my clinical questions.	68.9%	91	9.9%	13	21.2%	28
I valued interacting on-line with other students in the threaded discussions.	56.6%	73	18.6%	24	24.8%	32
I valued interacting on-line with faculty in the threaded discussions.	58.0%	76	16.0%	21	26.0%	34
My clinical preceptor was supportive of providing the time needed to work on the on-line clerkship.	58.0%	76	15.3%	20	26.7%	35

EBM—evidence-based medicine

Limitations

There were several potential limitations to this study, including that students' incoming, baseline literature-searching skills were not fully assessed. In addition, although the on-line curriculum is designed so that it does not demand increased time commitment from clerkship clinical preceptors, individual faculty might have been more or less familiar with and enthusiastic about incorporating EBM into their activities. Also, our success might result in part from enthusiastic faculty, thus possibly limiting generalizability of our findings to those institutions with similarly committed educators.

Conclusions

The family medicine on-line clerkship curriculum allows students to participate independently in e-learning modules and to perform coursework at times and locations that are most suitable to their clinical schedules. The on-line curriculum is student focused and rich with opportunities for interaction among students and faculty. It teaches core evidence-based practice skills, providing students with a framework and tools for integrating EBM into their own clinical practices.

Experts argue that EBM training, coordinated with evaluation and feedback opportunities, should be incorporated into all 4 years of the medical school curricu-

lum.^{22,23} In family medicine, as in other departments, e-learning technologies can be used to help achieve this goal.²⁴ We anticipate that family medicine educators and practitioners will increasingly take advantage of emerging e-learning technologies to improve the quality of EBM education and practice.

Acknowledgments: Financial support was received from The Robert Wood Johnson Foundation, through a Generalist Physician Faculty Scholars Award to Dr Wiecha and by HRSA Training in Primary Care Medicine and Dentistry Grant #5 D56HPO3355-02-00.

This research was previously presented in abstract form at the Annual Meeting of the Medical Library Association, May 23, 2004, in Washington, DC, where it was winner of the 2004 MLA Research Award.

Corresponding Author: Address correspondence to Dr Wiecha, Boston University, Department of Family Medicine, Boston Medical Center, Dowling 5 South, 1 BMC Place, Boston, MA 02118. 617-414-4465. Fax: 617-414-3345. John.Wiecha@bmc.org.

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