Educating Physicians in Evidence Based Medicine: Current Practices and Curricular Strategies

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Educating Physicians in Evidence Based Medicine: Current Practices and Curricular Strategies

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Table of Contents

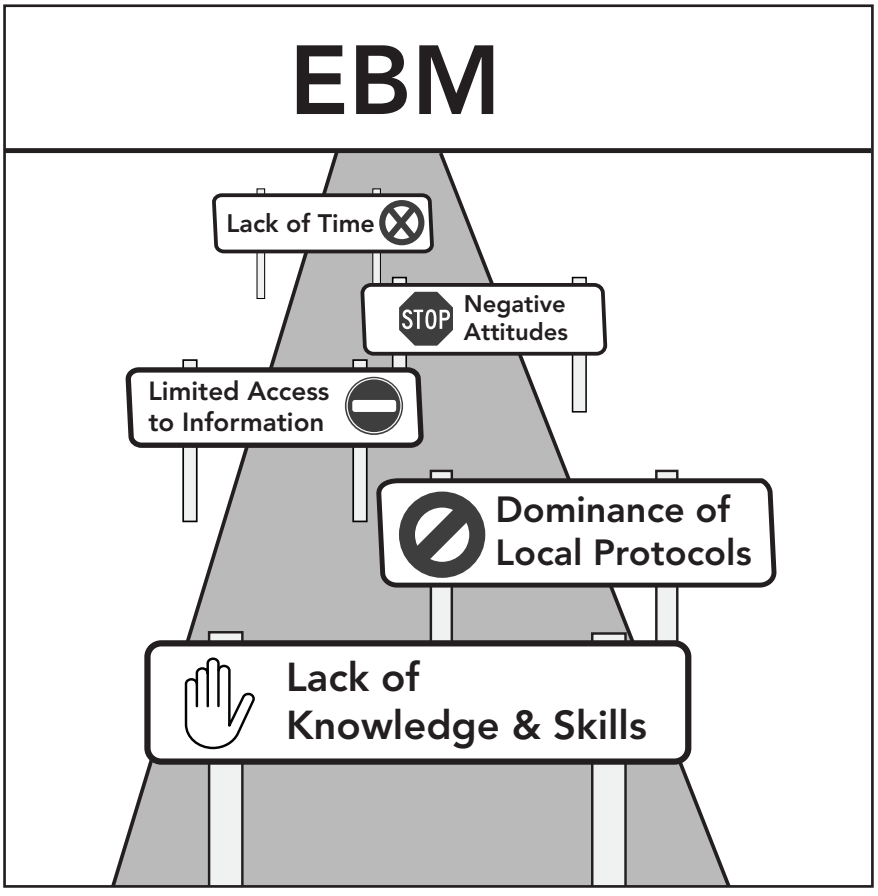
CHAPTER 1

Introduction

Due to the explosion of medical research and resulting biomedical information, physicians cannot expect to provide patients optimal care if they rely only on information that they were taught in their training.[1] In the early 1990's, Evidence-based Medicine (EBM)[2] was introduced to empower physicians[3] to pose and answer clinical questions in order to close the gap between the proliferation of knowledge and their clinical practice.[4] Since its introduction, EBM has become an expectation of clinical practice and is considered the "gold standard" of clinical care.[5] Connected with reduced clinical errors, more individualized care, cost savings, increased consistent care for patients[6,7] and physicians' lifelong learning,[8] EBM is now required by professional organizations and accrediting bodies for certification and is a requisite component in many medical school curricula.[9]

Yet, EBM is not ideally practiced in clinical care due to a spectrum of factors. Researchers have identified major barriers to EBM that include lack of time, negative attitudes towards EBM, limited access to information, the dominance of local protocols and lack of knowledge and skills to practice EBM.[10-14] See Figure 1.

Figure 1: Barriers to practicing EBM



While it is important to take into consideration the multi-factorial barriers to EBM it is notable that physicians report a lack of knowledge and skills in light of the ubiquitous inclusion of EBM training in medical education.[9] This suggests a need to further examine EBM education to understand the current best practices and how medical education might address these factors, which pose a challenge to preparing physicians to practice EBM.

This introductory chapter provides background information on EBM, including various educational approaches for training physicians in this domain, and describes the development of our research questions to address and enhance EBM education. The chapter begins by introducing the historical context, definitions, recommended steps for practicing EBM and models associated with the steps. The chapter also addresses the current state of EBM in clinical care and considers challenges to its practice, including challenges posed by the lack of available information on EBM training. This chapter concludes by presenting the related research questions that this dissertation addresses and lays out the studies to be conducted to address these questions.

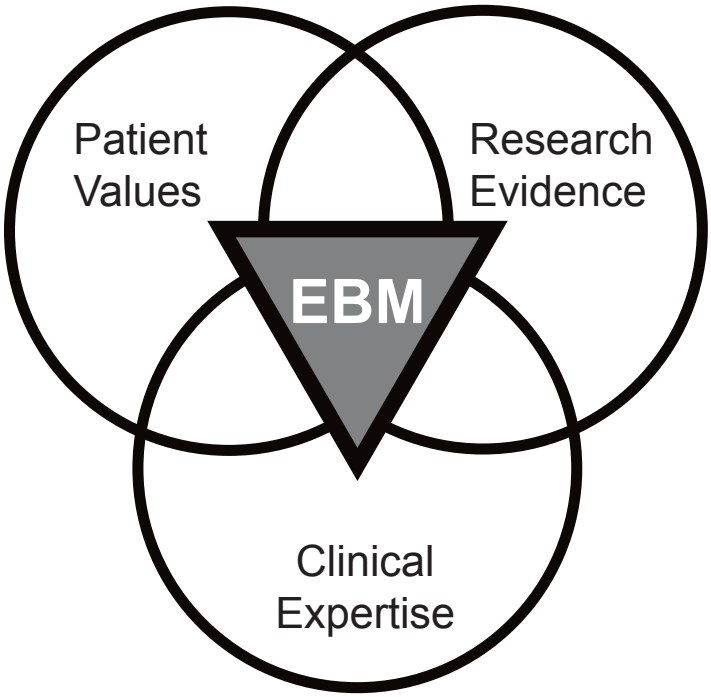
The definition of EBM

In 1992, Gordon Guyatt, announced the emergence of "new paradigm" for practicing medicine and learning medicine, which he dubbed Evidence-Based Medicine (EBM).[3] Guyatt defined EBM as the "ability to assess the validity and importance of evidence before applying it to day-to-day clinical problems".[2] Building on Guyatt's work, 1996, Sackett published the landmark paper "Evidence based medicine: what it is and what it isn't".[15] This paper includes the most commonly cited definition of EBM as: "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients". Although Sackett's definition is often cited, recent alternatives, such as the 2005 Sicily Statement on Evidence Based Practice have been proposed that recognize other health professionals such as nurses, pharmacists and dentists as evidence-based practitioners.[4] Additionally, this statement emphasizes the role of the patient and their wishes in EBM, which aligns with the sentiment that "real EBM has the care of the individual patients as its top priority"[16] and the reminders of EBM advocates that evidence alone is not enough to render clinical decisions.[17] In this way, EBM can be envisioned as the intersection of patient values, research evidence and clinical expertise to make clinical decisions. (See figure 2).

As noted above, a range of healthcare professions have adopted the principles of EBM into their practice. Some professions have chosen to tailor the name of the EBM concept to better represent their profession. In dentistry the use of evidence is referred to as Evidence-based dentistry (EBD), in public health Evidence-based public health and in nursing Evidence-based nursing (EBN). Related to this, there is a movement to rename EBM for all professionals as Evidence-based practice (EBP) to recognize the

multiple professions that utilize this concept.[4] Although, we acknowledge the multi-disciplinary nature of this model, in this thesis, the term Evidence-based medicine or EBM is used as the thesis focuses solely on the use of evidence by physicians.

Figure 2: EBM is the intersection of patient values, research evidence and clinical expertise to make clinical decisions

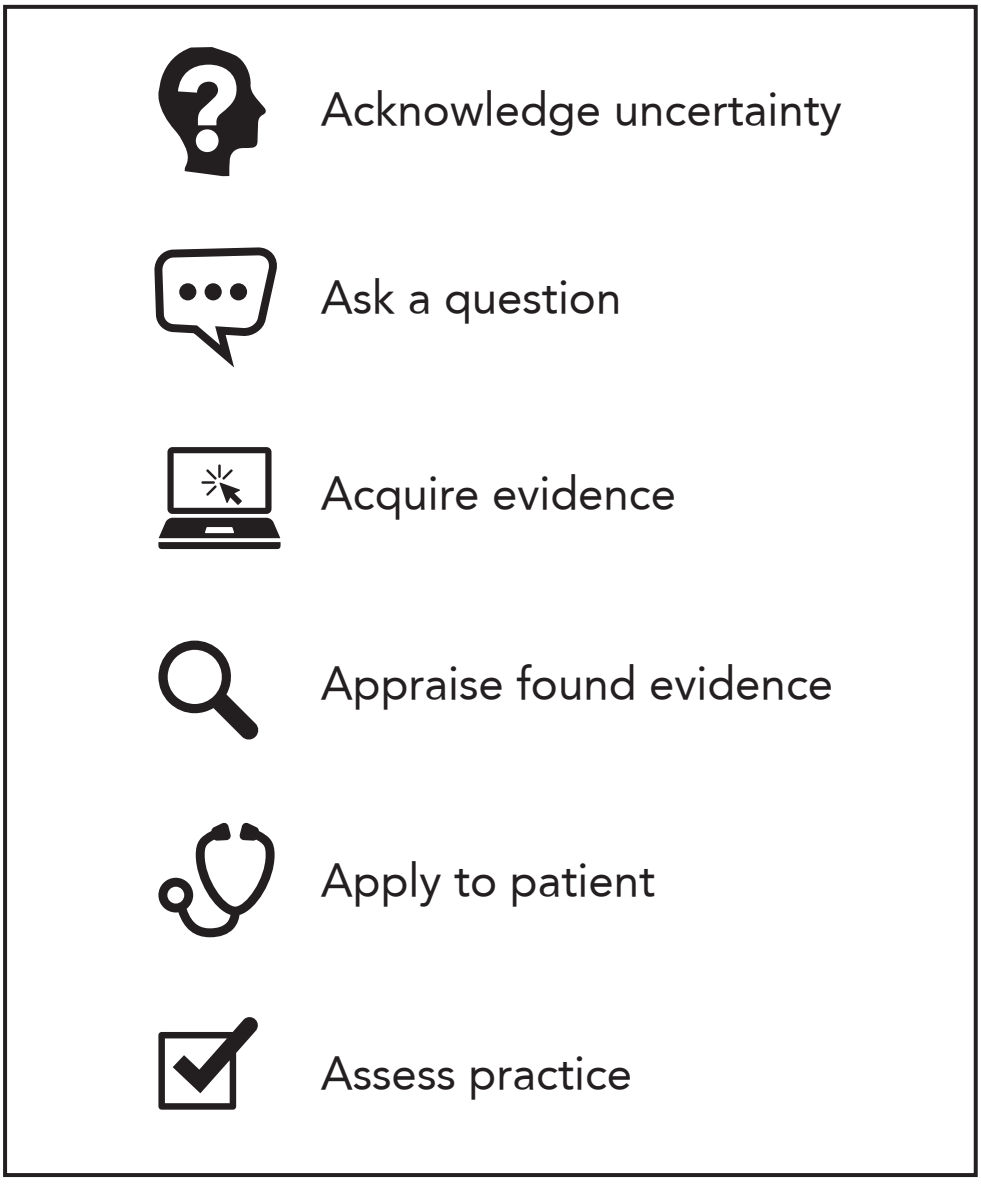


The practice of EBM

Although there is no official model for practicing EBM it is often characterized by the practice of five steps that were first introduced in 1992.[18] These steps are referred to as the "5A's" (Ask, Acquire, Appraise, Apply and Assess).[19] For example, when faced with uncertainty an EBM practicing physician will *ask* a clinical question, *acquire* related evidence by searching the biomedical literature, *appraise* the found evidence, *apply* it to her patient and then *assess* her practice. Despite being the prevailing model, the practice of the 5A's is not supported by an underlying theory or empirical evidence.[5] This model has also been criticized for being a doctor-centered approach removed from the specific wishes of the patient.[20] Yet, these steps are featured in key EBM textbooks such as *The User's Guide to the Medical Literature*[21] and *Evidence-based Medicine: How*

to practice and teach it.[22] More recently these steps have been expanded to include the precursor step of a practitioner acknowledging their uncertainty, which then triggers clinical inquiry. In the nursing literature, this step has been called Step Zero.[23] (See Figure 3)

Figure 3: The steps of EBM



Beyond the Five A's, there are three dominant approaches that focus on facilitating the practice of the five individual EBM steps: the PICO model, the 6S method and the use of *User's Guide to the Medical Literature*. These approaches have been suggested for use in practice and are also integrated into EBM training.

The PICO model is used to facilitate the formulation of clinical questions (Ask).[24] The PICO model encourages practitioners to formulate clinical questions based on the condition of their *Patient*, the *Intervention* that is under consideration, a potential *Comparison* to the intervention and the patient's desired *Outcome*. This approach helps users focus their clinical question and translate their uncertainty into relevant key terms for an optimized literature search.[25] The PICO approach has been integrated into medical education training.[26,27] A recent systematic review found that the PICO approach helped learners to improve the quality of their clinical questions.[28]

Another model is the 6S Model, which specifically addresses the Acquire evidence step. This model has been proposed to help physicians navigate their information landscape and guide them to the best evidence for practicing EBM.[22,29,30] The 6S Model depicts the information landscape as a hierarchical pyramid of information types ranging from single studies at the base of the pyramid to synthesized evidence reports at its tip. Using this model, physicians are encouraged to start and if possible stay at the top of the pyramid, drilling down only as far as necessary. This model provides physicians a general rationale for selecting information resources. Although there is limited information available as to the overall use and effectiveness of the 6S Model in practice it is often included in EBM educational materials.

Although there is no "gold standard tool" for critically appraising the biomedical literature,[31] one prevalent approach has been the use of the critical appraisal worksheets from the *User's Guide to the Medical Education Literature*.[21] These worksheets provide users with a structured list of questions to pose in relation to an individual study to help the user determine the validity of a particular study. Users select which worksheet to use depending on their clinical question type, e.g. therapy, diagnosis, prognosis questions. The use of these structured critical appraisal worksheets approach have also been incorporated into EBM training activities, especially in journal clubs.[32]

The above sections describe the logistics of practicing EBM and the three models that are used to teach EBM. Yet, despite this step-wise approach and the general agreement by physicians that EBM is important, it is sub-optimally practiced in clinical care.[4,16] The sub-optimal practice of EBM is attributed to a variety of factors and barriers, including systems factors (e.g. lack of time), attitudinal issues (e.g. negative associations with EBM), and lack of knowledge and skills (e.g. inability to locate evidence).[10-14] For example, researchers have identified that physicians feel that

searching for biomedical literature is overly time consuming due to the incredible volume of available evidence and therefore consider acquiring evidence to be a barrier to practicing EBM.[11] Additionally, physicians have reported that they find critical appraisal of evidence and its application to individual patient situations to be quite challenging and therefore another barrier to EBM practice.[14]

While all of these factors and barriers to EBM are concerning, physicians' lack of knowledge and skills to practice EBM[12] despite efforts made to provide EBM training, especially at the undergraduate medical education level (UME)[9] is especially concerning. This indicates that there may be a disconnect between the EBM training provided in UME and the ability of learners to transfer this learning into practice, which signals a need to more closely examine EBM education in UME.

The teaching of EBM

For over twenty years, EBM has been included in the curricula of medical schools.[33] However, despite the inclusion of EBM in medical school curriculum little is standard about the way in which it is implemented.[34-36] For example, one institution might feature EBM in year one integrated into problem based learning,[37] while another introduces EBM training into clerkship training in the fourth year of medical school at a Taiwanese institution.[38] EBM is also being taught using a wide variety of teaching methods with some institutions leveraging online instruction[36] and others focusing on EBM delivered in the patient's room.[39] Additionally, the coverage of the steps of EBM has been reported as uneven with much of the focus on critical appraisal skills.[40] This emphasis on critical appraisal has resulted in less coverage of what have been dubbed the critical "initiation skills"[41] of asking clinical questions and acquiring information therefore creating an uneven approach to EBM training. Lastly, at this time there is no conceptual framework for evaluating EBM training[42] and no clear evidence on the most effective methods for training[43]. In light of the lack of a standardized approach to teaching EBM and evidence for best practices, the broader fields of education and instructional design may provide some insight into approaches that can potentially improve EBM training.

A need for theoretical grounding of EBM education teaching

The exploration and use of relevant educational theories can provide a better understanding of learning and inform the design of educational initiatives.[44,45] Educators have advocated for increased use of educational theory and evidence-based instructional design to inform medical education curriculum design.[46,47] As noted there is no definitive approach for teaching EBM. Similarly there is no central educational theory or strategy that has been adopted for guiding the design of EBM training.

In some rare cases, at the residency level medical educators have identified the use of educational theory to inform EBM teaching. For example, Green designed an EBM curriculum based on Knowles' Adult Learning Theory or andragogy.[48] In this curriculum, medicine residents were engaged in 20 weeks of training that stressed the importance of adult learning principles set forth by Knowles such as activating learners' prior knowledge, and engaging learners in task-based EBM activities that mirror real-life practice of EBM.[49] A family medicine residency also explicitly leveraged educational theory by basing their training on Collins' Cognitive Apprenticeship model.[50] In this training, residents were assigned a learning coach who role modeled EBM skills, provided scaffolding, gave feedback and encouraged reflection on EBM activities.[51] At the medical school level, a recent systematic review of EBM educational interventions identified 27 studies of EBM training in medical schools.[43] None of these studies specified the use of an educational theory to guide their training.

As noted the use of educational theory is a valuable in guiding training.[45,47] Therefore, medical educators at the undergraduate level might consider those approaches presented by their colleagues in graduate medical education to inform their training. However, as EBM is a complex cognitive task that is practiced in the social workplace other social and cognitive learning theories may also be of interest, including Social Cognitive Theory,[52] Situated Learning Theory,[53] Workplace Learning Theory[54] and Cognitive Load Theory.[55]

While education guided by the above theories may be a viable option for designers of EBM education, it is difficult to determine their specific fitness in part due to the current lack of information available on existing EBM training. At this time there is limited knowledge as to how EBM is offered in medical schools and what are best practices, how learners might see EBM skills practiced by faculty role models and how instructional design principles might be applied to EBM training. Related to these gaps in knowledge, this thesis attempts to answer the following research questions: *How is EBM practiced? How is EBM taught in medical schools? What educational models can guide the design of EBM curricula and related pedagogical strategies?*

To answer these research questions, we conducted several studies. To begin we focus on *How is EBM practiced*. In Chapters 2 and 3, we investigate the use of EBM among health personnel in clinical care in order to better understand EBM in practice and inform the design of EBM education. These chapters focus on the physician information needs and the acquisition of relevant evidence. These two EBM skills are less prominent in the biomedical literature and less frequently covered in medical education training[41] yet are critical as they kick-start the EBM process. Based on interviews with general practitioners from the United States and the Netherlands, we attempt in Chapter 2 to identify physician information needs and how these information needs relate to their use of primary and secondary literature via the

information resources PubMed and UpToDate. In Chapter 3, we present a web log study that investigates the use of the primary and secondary literature over the course of a year at a major academic medical center in the context of patient care.

In studies presented in Chapters 4 and 5, we next examine *How is EBM taught in medical schools?*. In Chapter 4, we aim to characterize educational initiatives targeting the improvement of undergraduates' EBM skills. This study is based on a systematic review of the medical education literature published between 2006-2011. In Chapter 5, we report on a study in which we interviewed faculty at North American medical schools that graduate students confident in their abilities to practice EBM. Our goal was to learn about challenges to students learning EBM and to identify the ways in which these medical schools have approached these challenges in their curriculum.

Building on the findings in the previous chapters and instructional design principles, we next answer *What educational models can guide the design of EBM curricula and related pedagogical strategies?* In Chapter 6, we suggest the application of van Merrienboer's Four Component Instructional Design 4C/ID model to EBM instruction and illustrate how EBM teaching and curricula could be optimally designed. Lastly in Chapter 7, we summarize the main findings of these studies and consider the implications for clinical practice and medical education. Areas of future research are also considered.

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CHAPTER 2

Characterizing physicians' information needs at the point of care

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Characterizing physicians' information needs at the point of care.
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Abstract

Physicians have many information needs that arise at the point of care yet go unmet for a variety of reasons, including uncertainty about which information resources to select. In this study, we aimed to identify the various types of physician information needs and how these needs relate to physicians' use of the database PubMed and the evidence summary tool UpToDate. We conducted semi-structured interviews with physicians (Stanford University, United States; n=13; and University Medical Center Utrecht, the Netherlands; n=9), eliciting participants' descriptions of their information needs and related use of PubMed and/or UpToDate. Using thematic analysis, we identified six information needs: refreshing, confirming, logistics, teaching, idea generating and personal learning. Participants from both institutions similarly described their information needs and selection of resources. The identification of these six information needs and their relation to PubMed and UpToDate expands upon previously identified physician information needs and may be useful to medical educators designing evidence-based practice training for physicians.

Physicians have many information needs[1-2] that, when satisfied, contribute to improved patient care outcomes[3] and physicians' lifelong learning.[4] Information needs are an "expression of missing information that is required to accomplish a specific task".[5] Yet, many physician information needs go unmet[6] due to a variety of barriers,[7] including uncertainty about which information resources to use.[1,7] The number of information resources available to physicians is continually growing and there is a lack of guidance about which information resources to access at the point of care.[8]

Fundamentally, the uncertainty surrounding information resource selection is an education problem. Researchers have suggested that knowledge of physicians' information needs at the point of care may facilitate the development of customized training for resource selection in practice.[9-10] To design such training, there is a need to identify practicing physicians' information needs and their relationship to information resource selection. Much of the available research on physician information needs is based on the analysis of clinical questions and classification of their types. This research has been used to create taxonomies, such as Ely's Taxonomy of Generic Clinical Questions,[11] that inform the design of informatics solutions, including the creation of question banks[6] and computerized search strategies.[12] Researchers have also examined physician information needs to inform the selection of topics for continuing medical education activities.[10,13] While valuable, these informatics and topic-driven approaches have not provided a strategy for medical educators to utilize information needs in training programs designed to help physicians select information resources in practice. Related to physicians' information resource use, much of what is known focuses on identifying which resources physicians use to answer clinical questions generally.[14-16] While this provides insight into resource selection, it does not link the use of information resources to specific information needs, which have been found to shape physicians' approaches to searches.[17]

The primary aim of our research is to identify practicing physicians' information needs that can be satisfied by searching the biomedical literature. A secondary aim is to explore how information needs relate to physicians' use of PubMed and UpToDate.

Methods

Design

We employed a qualitative research methodology using semi-structured interviews to capture physicians' descriptions of their information needs in their own words.

Context

This study was undertaken at Stanford University Medical Center (SUMC) in the US from February to March 2012 and at University Medical Center Utrecht (UMCU) in the Netherlands from August to September 2012. Both centers are research-intensive academic medical centers that offer Evidence Based Practice (EBP) curricula and provide their physicians access to similar biomedical information resources. We selected these two medical centers because they are similar and to increase the generalizability of the findings.

Although physicians utilize a variety of information resources,[18] we focused on two commonly used information resources, PubMed and UpToDate, as these are highly utilized in clinical care.[15,19] For example, a recent study conducted using web log analysis reported that health personnel at an academic hospital accessed PubMed and UpToDate over 150,000 times in 2011.[15] Notably other information resources such as Clin-eGuide, Five-Minute Clinical Consult and Clinical Evidence were only accessed approximately 2000 times combined and the search engines Google and Google Scholar were similarly lightly used. Additionally, PubMed, a database, and UpToDate, an evidence summary tool, were also selected as they represent two major types of information resources. Both resources are quite different in the information they provide and their user experience. UpToDate is an evidence summary service that synthesizes available evidence on over 9,000 topics and provides a structured narrative summary.[20] PubMed is a search interface that connects users with over 23 million citations for biomedical articles and does not provide syntheses.[21]

Participants

We recruited internal medicine physicians because of the breadth of their discipline and information needs. Following approval by the SUMC human subjects review committee, one investigator (LAM), a lecturer in the Division of General Medicine Disciplines at SUMC, in consultation with a second investigator (KP), an internist, emailed 15 participants in their department an invitation to join the study. Two of the contacted internists declined to participate due to scheduling difficulties. At UMCU, following ethical approval by the Netherlands Association for Medical Education Ethical Review Board, another investigator (EtB), a professor and internist at UMCU, emailed 20 internists known to her. Nine internists scheduled interviews and 11

declined due to scheduling issues. Scheduling interviews at UMCU was difficult because the timeframe for interviews overlapped with the UMCU summer holiday season.

Data Collection

The interviewer (LAM) used the same English semi-structured interview guide (See Appendix 1) for all participants no matter if they were interviewed either in-person or by phone. The multi-disciplinary author team designed the interview guide based on a review of the literature. We piloted the interview protocol with US and Dutch internists and made minor refinements based on their feedback. At UMCU, we also piloted the interview guide with a native Dutch-speaking internist to ensure that the use of English posed no problems.

Based on the interview guide the LAM first asked all participants to describe their clinical information needs. Following the description of their information needs, she requested that participants describe a clinical information need from their last day of practice and their process of satisfying that information need. Following their description, LAM specifically asked participants to indicate which of their overall clinical information needs would prompt the use of PubMed and UpToDate. All interviews were recorded and transcribed verbatim.

Data Analysis

We analyzed all transcripts using thematic analysis techniques to identify types of information needs and their relation to PubMed and UpToDate use.[22] To begin, two authors (LAM and BCO) familiarized themselves with the transcripts and identified passages from each transcript related to the aims of the study. Through multiple reading of the transcripts, they identified codes for participant information needs and their use of PubMed and UpToDate.

An interprofessional, multinational team (co-authors LAM, BCO, LLM, FvS, BK and KP) discussed the codes proposed by LAM and BCO and suggested additional codes based on their reading of the transcripts. After agreeing on the codes, team members coded at least four transcripts, including at least one US and one Dutch participant. Coders identified information needs and their relationship to the use of PubMed and/or UpToDate. The coders noted any cultural differences. LAM coded all transcripts and compiled all data for discussion by the coding group. Team members reached consensus on all coding. Based on the coding, LAM and BCO identified themes for information needs and PubMed and UpToDate use.

Results

Demographics/settings

Interviews were conducted with 22 participants (13 US, 9 Dutch) and occurred in-person (n=17) or by telephone (n=5). We did not detect differences in the interviewees' responses based on telephone or in-person interview. Table 1 shows participants' characteristics.

Table 1: Participant characteristics

	US Participants	Dutch Participants	Total Participants
Number of participants	13 (59%)	9 (41%)	22 (100%)
Mean years of practice	18.53 SD 13.97 Range 3–42 years	18.44 SD 11.07 Range 4–37 years	18.5 SD 12.80 Range 3–42 years
Year of Graduation 1970–1980	3 (34%)	3 (23%)	7 (32%)
1981–1990	2 (22%)	2 (17%)	4 (18%)
1991–2000	2 (22%)	3 (23%)	5 (23%)
2001–2010	2 (22%)	5 (37%)	6 (27%)
Male participants	8 (62%)	6 (66%)	14 (64%)
MD/PhD	0 (0%)	9 (100%)	9 (41%)
Participants reporting on inpatient settings	6 (46%)	4 (44%)	10 (45%)
Participants reporting on outpatient settings	7 (54%)	5 (56%)	12 (55%)

We did not find differences in information needs or resource selection based on nationality. Participant information needs also did not differ whether or not a participant possessed a PhD degree in addition to an MD degree. To offer a balance of perspectives, we included, where possible, quotes from both US (labeled S# for Stanford - US) and Dutch (labeled U# for Utrecht - Dutch) participants.

We identified six information needs: refreshing, confirming, logistics, teaching, idea generating and personal learning (see table 2). We also determined for which information needs participants selected PubMed and/or UpToDate.

Table 2: The six information needs identified

Reason	Definition
1. Refreshing	To update or aid in the recall of one's own known knowledge
2. Confirming	To check one's own knowledge for self-satisfaction or in preparation to speak, take action, advise patients, etc. To confirm another individual's or resource's knowledge/ coverage of a topic
3. Logistics	To answer practical questions to facilitate action
4. Teaching	To teach trainees through a variety of methods, including lecturing, role modeling, etc.
5. Idea Generating	To generate ideas for treatment, diagnosis or an overall sense of what is happening with a patient
6. Personal Learning	To foster one's own learning or satisfy curiosity

1. Refreshing

To refresh their knowledge and keep current, participants utilized both UpToDate and PubMed. In a few specific instances, participants perceived PubMed as better suited to their needs for refreshing knowledge. For example, when confronted with rare conditions, several participants selected PubMed in alignment with their perception of PubMed's relevance to "exotic cases" (U6). Additionally, participants often selected PubMed when they needed more current material to refresh their knowledge, which synchronizes with the perception that PubMed is relevant for locating "the latest information" (U8). Participants' decision not to select UpToDate in this situation also aligned with participants' uncertainty about the validity of UpToDate regarding its currency.

2. Confirming

Participants selected both PubMed and UpToDate when seeking to confirm their own knowledge. "Basically I want to see if we are thinking in the same direction. To see if my thoughts are almost the same as they are in UpToDate" (U9). In some cases, participants wanted to confirm something said by others, which typically resulted

in using PubMed. For example when hearing colleagues quote clinical trial findings, PubMed was used to locate the trials. This behavior is consistent with participants' frequent description of PubMed as relevant for accessing primary literature. Lastly, participants reported the need to confirm the content of UpToDate evidence summaries by searching PubMed for primary literature or utilizing the reference links available in UpToDate evidence summaries.

3. Logistics

UpToDate was the resource primarily used when participants needed to answer logistical questions such as "what is the half-life of [medication xxx]?" (S4). This links to participants' perception of UpToDate's content as relevant to straightforward, easy to answer, action-oriented questions. Participants' description of the ease of using UpToDate, in contrast to the high level of effort required for PubMed, suggests one reason why PubMed is used less than UpToDate for logistical questions.

4. Teaching

Participants role modeled both PubMed and UpToDate use for trainees, which we defined as informal teaching. One participant said: "I try to look up the day-to-day patients as well as patients with rare diseases when I am working with residents. We usually look up these questions when we are behind the computer together and we always use UpToDate or PubMed" (U5). Although participants role-modeled both resources, PubMed was referenced in terms of more formal training such as "question-of-the-week" activities or structured demonstrations of the PubMed interface. Participants identified their use of PubMed with trainees specifically as teaching whereas UpToDate was not labeled as such. In teaching scenarios, PubMed was often linked with EBP and several participants referenced it in the context of EBP teaching activities. Related to teaching, several participants suggested a need for additional PubMed training, guidelines for expert PubMed searching, and opportunities for feedback from PubMed experts. These requests synchronize with the perception of PubMed as difficult to use but privileged in demonstrating EBP searches.

5. Idea generating

Participants used both PubMed and UpToDate to generate ideas. One participant said, "I don't know which type of chemotherapy for this tumor. I have no idea." (U5). In this case, he consulted UpToDate, which was a common approach when participants knew the patient condition but needed ideas on how to proceed. This is associated with participants' perceptions of UpToDate as relevant to straightforward, action-oriented questions. Alternatively, participants used PubMed as a clinical decision support system to figure out patient conditions for which they have little information or are "grasping at straws" (S4) in terms of knowing how to proceed.

6. Personal learning

Participants used both PubMed and UpToDate for personal learning, although PubMed was more frequently employed for this information need. This intertwines with participants' perception of PubMed's relevance to EBP, which is often associated with lifelong learning. In some cases, participants felt that PubMed's perceived value as a learning tool outweighed its applicability to clinical care. Several participants stressed the importance of PubMed for medical students who are in the "just-learning phase"(S11) and who are required to participate in EBP curricula. Several participants mentioned that using PubMed for learning was not realistic during patient encounters due to time constraints and was often done after work. "If I am trying to learn more about something then I will [use PubMed]. But I don't think I've ever used [it] during a patient visit or during clinic" (S1). This is associated with participants' perception of PubMed as "challenging to use, especially for clinical care" (S12).

Although asked to focus on patient-care questions, several participants mentioned using PubMed when undertaking research. In some cases, participants noted that PubMed was more relevant to research and less so for clinical care. "PubMed, I do use it all the time. But I use it for more kind of research or academic questions and a lot less for patient-care type questions" (S1). This reasoning connects with participants' perceptions that PubMed requires a high level of effort to use it effectively. They considered PubMed feasible in the context of research when less time pressure was felt. Participants did not mention using UpToDate for research.

Overall participants identified using both PubMed and UpToDate to satisfy each of the six information needs. In some cases, an individual mentioned using both PubMed and UpToDate to satisfy an information need. For example, several participants reported using UpToDate and PubMed in tandem when needing to confirm knowledge. In these instances, there was some uncertainty about which resource to use first to satisfy their information need.

Discussion

Based on physicians' descriptions we identified six information needs related to patient care: refreshing, confirming, logistics, teaching, idea generating and personal learning. In addition, participants reported using PubMed for research purposes. We have also explored for which of these information needs physicians use PubMed (a database) and/or UpToDate (an evidence-summary tool) and learned that participants used both resources to satisfy the identified information needs.

Previous studies have identified physician information needs and created taxonomies of clinical questions to help automate physicians' access to information.[9-10] The six identified information needs in this study align somewhat with previous research.[6] For example, Ely's Taxonomy of Generic Clinical Questions[9,11] identifies five broad categories including diagnosis, management, and treatment. These three broad categories could be applied to the information needs of refreshing, logistics and confirming depending on the specific details of the information need. However, the six identified information needs in this study extend Ely's Taxonomy by adding teaching and idea generating. Further more, the information needs of personal learning and teaching, map to the physician roles of patient care provider, lifelong learner, researcher, educator, and scholar identified by the CanMEDS Physician Competency Framework,[23] which educators use in the Netherlands.[24] This alignment suggests the use of the six information needs for potentially structuring an educational approach to support physicians in the spectrum of roles that they are expected to undertake in their careers.

Medical educators have been called upon to create learning opportunities for physicians to relieve uncertainty about information resource selection.[9-10] Approaches driven by information needs have been suggested.[9-11] We found that physicians in our study turned to different information resources for similar information needs. This finding may relate to physician's uncertainty about resource selection and could highlight physician's need for more knowledge or skills to select the optimal resource for a particular information need. The six identified needs may be used to inform these educational approaches. However, future research would be needed to investigate the feasibility of using of this approach in practice and to further understand physician information needs in relation to resource selection.

Another possible interpretation of our finding that participants used both PubMed and UpToDate to satisfy similar information needs is that physicians' information needs are complex and case specific within the context of a particular information need. For example, participants noted use of both PubMed and UpToDate for teaching, but they preferred PubMed when in formal educational settings. Similarly for idea generating participants tended to turn to UpToDate when they knew the patient's condition, but selected PubMed when the patient's condition was unknown. This nuanced use of information resources, which appears to depend on the context and content of physicians' information needs (e.g. presence of trainees, patient factors, criticality of the situation, etc.), raises important issues for designing training. There may be no simple solution or algorithm for training physicians to select information resources. Instead, we may need to design training that helps physicians evaluate information resources in the context of a variety of factors such as the type of information need, features of the situation, and other people involved.

This study has several limitations. We interviewed physicians in only two countries (the US and the Netherlands), within two similar academic medical centers (Stanford and Utrecht), and within one specialty (internal medicine). Future studies might include participants from other countries and other medical specialties. This study also only focuses on two information resources, PubMed and UpToDate, which although quite popular and representative of two major types of information resources are not the only information resources physicians use. We suggest that future studies might investigate a broad range of information resources used by practicing physicians, including PubMed and UpToDate, to better understand how and why physicians use these resources to satisfy each of the identified six information needs. Additionally, this study focused on physicians within academic medical centers. Future research should also examine the information needs of physicians in non-academic settings. As stated, all interviews were conducted by LAM, a medical librarian at Stanford, which had potential to bias the responses of those familiar with her role. In our analysis we did not detect any differences in between the populations that suggest bias on this account.

Conclusion

Physicians have a variety of information needs at the point of care including refreshing, confirming, logistics, teaching, idea generating and personal learning. In addition, they mentioned using PubMed for research purposes. The identification of these six information needs and their relation to PubMed and UpToDate expands upon previously identified physician information needs and sheds light on the overall complexity of physicians' information needs. The identified information needs may be a useful starting point for designing evidence-based practice training for physicians.

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Appendix 1

INTERVIEW GUIDE

- What information need triggers you to pose a clinical question based on a patient encounter and to search for answers in the biomedical literature?

- Please walk me through your general search strategy that you use to find information to answer your clinical question? You may find it helpful to think about your last half-day clinic or inpatient service experience and then more generally.

- We know that UpToDate is a popular resource.
    - How would you characterize UpToDate?
    - Are there any particular types of questions that lend themselves to UpToDate?

- We know that Pubmed is a popular resource.
    - How would you characterize PubMed?
    - Are there any particular types of questions that lend themselves to PubMed?

CHAPTER 3

Access of primary and secondary literature by health personnel in an academic health center: Implications for open access

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Access of primary and secondary literature by health personnel in an academic health center: Implications for open access. *Journal of the Medical Library Association.* (2013). 101(3):205-212.

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Abstract

The research sought to ascertain the types and quantity of research evidence accessed by health personnel through PubMed and UpToDate in a university medical center over the course of a year in order to better estimate the impact that increasing levels of open access to biomedical research can be expected to have on clinical practice in the years ahead. Web-log data were gathered from the 5,042 health personnel working in the Stanford University Hospitals (SUH) during 2011. Data were analyzed for access to the primary literature (abstracts and full-text) through PubMed and UpToDate and to the secondary literature, represented by UpToDate (research summaries), to establish the frequency and nature of literature consulted. In 2011, SUH health personnel accessed 81,851 primary literature articles and visited UpToDate 110,336 times. Almost a third of the articles (24,529) accessed were reviews. Twenty percent (16,187) of the articles viewed were published in 2011. When available, health personnel in a clinical care setting access the primary literature. While further studies are needed, this preliminary finding speaks to the value of the National Institutes of Health Public Access Policy and the need for medical librarians and educators to prepare health personnel for increasing public access to medical research.

The prospect that new technologies and policies will allow health personnel to increase the use of research evidence in clinical practice creates the potential for improving healthcare of individuals and populations,[1-2] and facilitating lifelong learning for health personnel.[3-4] In the last decade, an international movement to increase free online access to journals across all disciplines, including medicine, has made a greater proportion of the scholarly literature freely available outside of universities and research institutions. Today, roughly 20% of journal articles are freely available within a year of publication.[5] Among the factors helping to increase access has been the creation and growth of open access scholarly publishers, such as BioMedCentral and PLoS (Public Library of Science), from *Nature* to *The New England Journal of Medicine,* major publishers are now also exploring open access options.[6-7] Additionally, open access policies that require authors to post public copies of their publications, have been instituted by universities, such as the University of California, San Francisco,[8] and by major sources of research funds in the US, UK, Canada and Europe.[9-12] In 2008, the United States National Institutes of Health (NIH) Public Access Policy was enacted to ensure that the public, including health personnel, have access to NIH-funded research results within one year of publication.[13] The open access copies (which must be peer-reviewed final drafts if not the published version) are deposited in PMC (previously known as PubMed Central), an archive operated by the US National Library of Medicine (NLM). PMC currently contains 2.5 million articles and is accessed by more than 700,000 users daily.[14] In 2011, the manuscripts of 250,000 publications were deposited in PMC,[15] more than tripling earlier annual deposit estimates.[16-17] The NIH also reports a 75% policy compliance rate on behalf of current NIH-funded authors and their publishers.[15] All indicators point toward a future, if still a good number of years off, in which the vast majority of materials in scholarly biomedical journals will be publicly available.

Given that these various efforts to increase free access to biomedical research have affected only a small portion of the literature to date, it is difficult to understand what universal free access to the published literature would mean for clinical practice.[18-19] The lack of data to suggest the extent to which health personnel will actually take advantage of universal free access to scholarly journal articles poses a challenge for librarians and educators as they try to prepare for this new environment. Additionally, it is hard to assess and defend the NIH Public Access Policy without a means to judge the value of open access which it, and other policies, increasingly provide.

In general, studies of the information-seeking behavior of health personnel tend to use self-reported data. For example, researchers have reported that health personnel use a range of information resources,[20] with a strong preference for PubMed and UpToDate,[21] as well as Google.[22] Additionally, studies report that healthcare providers have a strong predilection for point-of-care resources to provide pre-appraised information.[23-24] Using a combination of survey and interview data, O'Keefe reported

similar findings and as well as a desire by physicians to have access to primary research evidence for patient care.[25]

Using a more objective approach, researchers have investigated direct use of PubMed via web-log analysis. For example, Herskovic and Dogan each studied PubMed and described users' search queries, citation hit counts and views of abstracts.[26-27] Both of these studies found high use of PubMed and provide valuable data related to user search patterns; however, they provide little or no data related to the types of literature accessed (e.g. review articles, clinical trials, etc.). Herskovic concluded that users' PubMed search habits resemble general web search strategies, but acknowledged as a limitation of his study that he was unable to track click-throughs to article results within PubMed.[26] Dogan noted that the size of a user's result set influences his or her decision of whether or not to click on results.[27] Although valuable, these findings relate to use of only a single information resource, PubMed, and thus may have limited value in the healthcare environment where, as noted above, a wide variety of information resources are typically used,[20-24] including secondary literature resources, such as UpToDate.[2] Additionally, these results are based on studies of short term behavior, such as searches in a single day or month, and did not restrict results to health professionals.[26-27] Most importantly, these studies do not provide details on use of the primary literature; they do not identify article publication types, publication dates and sources accessed. These data would be of considerable value for librarians in selecting materials for their collections and for policy makers prioritizing materials for public access.

The study reported here seeks to improve our understanding of primary literature accessed by those engaged in clinical care. It examines the annual access patterns of health personnel in a university medical center where the biomedical research literature indexed in PubMed, as well as the secondary literature resource UpToDate, is easily accessible. While an academic medical center represents a special case of a clinical environment – one likely to be at the high end of expected clinical use of research – it nonetheless offers a useful starting point in assessing the extent to which clinicians access the research literature when it is readily available. Four questions were the focus of this study: 1) With what frequency do health personnel find and view abstracts and articles when they have relatively complete access to this literature; 2) How does the frequency with which articles are accessed compare to use of a research summary service such as UpToDate; 3) In gaining access to abstracts and articles, to what extent do health personnel go through PubMed compared to UpToDate; 4) Among the articles consulted by health personnel, what types of articles are most popular, how current are the articles, and in what journals do the articles most frequently appear?

Methods

Setting/Population

Data was collected using searches conducted within the physical confines of Stanford University's hospitals (SUH).[1]

The population consisted of individuals physically located in SUH who had access to the Stanford University Medical Center (SUMC) network. A large majority are health personnel, defined as "men and women working in the provision of health services, whether as individual practitioners or employees of health institutions and programs, whether or not professionally trained".[29] Approximately 5,000 health personnel were employed at SUH at the time of the study (See Table 1), and an additional approximately 100 Stanford medical students were undertaking clinical clerkships at SUH during the period in which data was gathered. Non-health personnel, such as patients, are also present in SUMC hospitals and can request access to the SUMC network; however, this group's use of the network, and more specifically the studied resources, was believed to be negligible. Although the data collection techniques did not permit the access patterns of specific individuals to be identified, it seemed reasonable to conclude that health personnel were the primary users of biomedical information in the hospitals. Individuals at SUH can gain access to the primary literature through Stanford's Lane Library.[2] (See table 1)

Table 1: Stanford University Hospitals Health Personnel

Medical Staff	1,907 (38%)
House Staff (Interns and Residents)	1,044 (21%)
Registered Nurses	1,937 (38%)
Licensed Vocational Nurses	17 (.3%)
Assistants	154 (3%)
Total	5,042 (100%)

1. As defined in this study, SUH includes the patient-care structures of Stanford Hospital (613 beds) and Lucile Packard Children's Hospital (311 beds) [28]. For readability, Stanford Hospital and Lucile Packard Children's Hospital are referred to as SUH throughout.

2. Lane Library's resources include approximately 8,000 e-journal subscriptions, 12,000 e-books and 700 databases, including PubMed, the Cumulative Index of Nursing and Allied Health (CINAHL), Scopus and Web of Science. Lane also subscribes to a small collection of secondary information resources that are designed for use at the point of care, including UpToDate, Clin-eGuide, Clinical Evidence and Five-Minute Clinical Consult.

To gauge the types and frequency of research literature accessed, this study collected and stored anonymized web logs from SUH web traffic generated physically within the hospitals on the Stanford University network and passing through Lane Library online systems from January 1, 2011 through December 31, 2011.

Data were collected for usage of Lane's online systems performed on hospital computers (both desktops and laptops), which are available throughout both facilities and are connected to the Stanford network. Data usage performed on mobile devices used within the hospitals, from outside of SUH or which bypassed the Lane Library website (in particular direct access of PubMed), were not included.

While on the Stanford network at SUH, individuals are able to connect with Lane Library's electronic resources from Lane Library's web pages, which include several clinically focused specialty information resource portals, and from within SUH's electronic health record system. All of these entry points to Lane resources were tracked for the study. Since the focus of the study was access to online resources, no attempt was made to measure access to print literature or to track efforts to obtain unavailable full text of primary literature by using services such as interlibrary loan

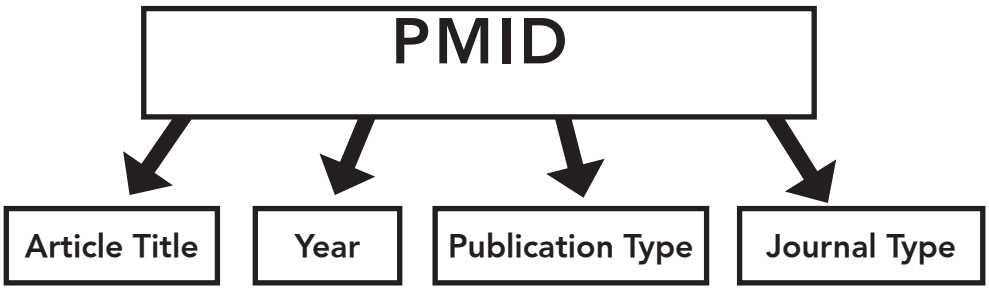
Information Resources Evaluated

PubMed and UpToDate were selected for study based on their prevalence in clinical care;[31-32] their ability to provide health personnel with research evidence; and their high level of use at SUH. PubMed is a free search interface providing access to MEDLINE, the NLM's premier bibliographic database, and containing references to more than 21 million articles in the life sciences with a concentration on biomedicine.[34] In 2009, PubMed was searched over 600,000,000 times.[35] UpToDate provides clinically focused summaries of the biomedical research written by physicians and referenced with links to primary research articles. UpToDate has more than 600,000 users worldwide[36] and is available in 17% of US hospitals.[37] These resources are heavily used at Stanford as well. For example, in 2011 UpToDate was accessed more than 100,000 times whereas Clin-eGuide, Clinical Evidence and Five-Minute Clinical Consult were only accessed approximately 2,000 times combined. Traffic to the search tools Google and Google Scholar via Lane was also initially selected for review, because of the general popularity of these resources.[33] However, traffic reported through the library web logs for these two resources was minimal; it accounted for less than 2% of total visits and clicks to primary literature. This may be because health personnel can access these resources directly rather than going through the Library's website.

Measures

UpToDate and PubMed both utilize a unique identifier (the PubMed ID, or PMID) to link out to primary literature. Using this identifier for articles retrieved via PubMed and UpToDate, we were able to identify detailed bibliographic information for each article accessed, including year of publication, publication type, journal title and article title [Figure 1]. By identifying each article's publication types, we were also able, when available, to determine governmental funding of an article. Article information was extracted using the National Center for Biotechnology Information's (NCBI) Entrez Programming Utilities[38] on March 15, 2012, when the majority of articles accessed would most likely be indexed for MEDLINE.

Figure 1: Article information extracted from a PMID using the NCBI Entrez programing utilities



Usage data were collected via a proxy server, which permitted the isolation of hospital traffic. The proxy server recorded a user's session in a standard web-log format for later processing and analysis. These web logs contained a unique identifier for each session, but no user-specific identification. Information requests, filtered from proxy logs, generated the following data: a timestamp; a unique session string; the requested resource; and referring page. Using this information, overall use of PubMed and UpToDate could be tracked using the appropriate entrance URL, associated with a session and a timestamp. Session data collection ended when a participant closed the browser or was idle for more than 60 minutes. All data extracted from proxy logs were stored in a relational database for reporting purposes.

[3.] This study focused on describing access to primary and secondary information resources, and did not attempt to measure the utility of the information accessed or its application to patient care.

Three measures were used to determine use and access: 1) visits to PubMed and UpToDate 2) views of abstracts and 3) views of primary literature articles.[3] A "visit" was defined as a user clicking on a link to enter PubMed or UpToDate. Multiple clicks to enter the same resource within a single user session were counted as a single visit. An abstract "view" was defined as a click in PubMed of an article title and in UpToDate a click on a reference link. A "view" of a primary literature article was defined as a click on a full-text link. In UpToDate, full-text links to literature were labeled "Check for full text availability" or "PubMed." In PubMed, links to literature took the form of a publisher icon or an OpenURL link resolver button located beside the abstract view of the article. In both PubMed and UpToDate, literature links contain PMIDs, which can be used to identify the specific article accessed. Multiple clicks to the same article within a single user session were counted as only a single view, as is commonly accepted in web log analysis.[39]

Analysis

We compiled descriptive statistics (views, publication date, publication type, journal title, and article title) of the articles accessed.

Results

In 2011, SUH health personnel visited UpToDate and PubMed a total of 157,580 times. UpToDate was visited 110,336 times, more than twice as often as PubMed (47,244 visits). A visit to PubMed typically led to the viewing of 2.69 abstracts and 1.68 research articles. Visits to UpToDate led to clicking through its hyperlinked bibliographies to the primary research literature only 2,474 times, accounting for only 3% of the 81,851 research articles viewed during the year from these two platforms. (See table 2)

Table 2: Site visits, abstract and article views by information resource for 2011.

Sites	Site Visits N (%)	Abstract Views	Article Views	Mean Abstract Views Per Visit	Mean Article Views Per Visit
PubMed	47,244 (30%)	127,197 (95%)	79,377 (97%)	2.69	1.68
UpToDate	110,336 (70%)	6,210 (5%)	2,474 (3%)	.06	.02
Total	157,580 (100%)	133,407 (100%)	81,851 (100%)		

In some cases, articles were viewed more than once. For example, there were six articles each having 20 or more viewings. The most commonly viewed article (34 views) was an early 2011 release of a case report on heart disease,[40] which is available from Elsevier's Science Direct website to non-subscribers for $31.50. Only one of these six articles (16%) — a clinical trial (21 views)[41] — was freely available.

Among the articles viewed, the most popular type was the review, which summarizes and draws conclusions from a wide range of research on a single topic (See table 3).

Table 3: Most common publication types of full-text views during 2011.

Publication Types[a] (n=57)	**Views**
Review	24,529 (30%)
Clinical Trials[b]	10,261 (12%)
Case Report	9,136 (11%)
Comparative Study	7,033 (9%)
Guidelines	1,640 (2%)
Meta-analysis	1,403 (2%)
Other	27,849 (34%)
Total	81,851 (100%)

Notes:

[a] Publication type assigned by National Library of Medicine (NLM).

[b] Aggregate of NLM classifications: Randomized Controlled Trial (4,753 views); Clinical Trial (3,484); Phase II Clinical Trial (750); Phase III Clinical Trial (594), Controlled Clinical Trial (343); Phase I Clinical Trial (328); and Phase IV Clinical Trial (10).

We examined views of US government-funded articles for articles published between 2008 (the start date of the NIH Public Access Policy) and 2011. SUH personnel viewed 6,917 articles (8%) funded by US government agencies and published in this time period. Of these articles, 5,763 (7%) were funded by the NIH and 1,154 (1%) were not NIH funded (See table 4), but instead funded by other government agencies such as the Departments of Education, Energy, Defense and Justice.

Table 4: Number of articles acknowledging United States Government Research Support*

Year	NIH Supported			Other Governmental Agency Support			Total
	Research Support, N.I.H., Extramural	Research Support, N.I.H., Intramural	Total	Research Support, U.S. Gov't, Non-P.H.S.	Research Support, U.S. Gov't, P.H.S.	Total	
2011	1952	147	2099	270	142	412	2511
2010	1705	115	1820	224	133	357	2177
2009	1011	64	1075	121	104	225	1300
2008	728	41	769	98	62	160	929
Totals	5396	367	5763	713	441	1154	6917

*Articles viewed in 2011 and published between 2008–2011.

The vast majority of articles viewed were published within the past decade, with 16,187 (20%) falling within the current year of the study. (See table 5).

Table 5: Year of publication of articles viewed in 2011.

Years	Articles Viewed – n (%)
2011	16,187 (20%)
2002–2010	51,187 (63%)
1844–2001	13,777 (17%)

Articles were accessed from 4,967 journals. Thirty-nine journal titles accounted for the first quartile of article views; the second quartile consisted of 137 titles; the third quartile included 375 journal titles; and the fourth quartile 4,407 titles.

Discussion

Despite the frequently mentioned barriers to accessing evidence in clinical settings — lack of time[4] and poor information retrieval skills[42]— SUH health personnel took frequent advantage of the published literature. Although UpToDate was used more frequently than PubMed, which is consistent with previous studies,[25,43-44] health personnel did access primary literature using both PubMed and UpToDate, indicating that UpToDate alone is not sufficient to support information-seeking in patient care. Of course due to their inherently different content and structure, it is not possible to directly compare a visit to UpToDate to the viewing of a scholarly article. This study attests, however, to the degree to which both UpToDate and the primary literature form integral parts of clinical practice among health personnel. It indicates that health personnel find having access to both primary and secondary sources of considerable value, which, in turn has implications for library collection development and the training of health personnel in information literacy skills.

SUH health personnel accessed 57 of the 151 publication types assigned by NLM, suggesting that access to a wide range of publication types is desirable in patient care. Twenty-three percent of the views were to article types associated with the practice of evidence-based medicine (EBM) (clinical trials, comparative studies and meta analysis), indicating that article selection may be influenced by the desire to practice EBM. EBM is the "conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients"[45] and is linked with the promotion of individualized care and best practices.[1] Current best evidence has been defined as "clinically relevant research, often from the basic sciences of medicine, but especially from patient centered clinical research",[45] making the use of clinical trials, particularly randomized control trials, a popular choice for practicing EBM.[46]

The preponderance of review studies among the articles viewed (29% of the articles selected) suggests that clinicians need review articles despite easy access to summaries and reviews of the literature in UpToDate.

More than 10,000 clinical trials were accessed, with close to 50% (4,753) of those qualifying as the gold-standard randomized control trials. Clinical trials allow the reader to hone in on a single factor, whether in treatment or patient characteristics. In 2011, the NIH invested $3.5 billion to fund clinical trials research.[47-48] Clearly, the value of these trials to health personnel, and thus the public at large, is increased as this research is accessed in clinical settings.

Our findings also demonstrate that health personnel access articles funded by US government agencies other than the NIH. This speaks to the importance of legislative initiatives, such as the recently introduced Fair Access to Science and Technology Research Act, intended to extend the NIH Public Access Policy to other federal agencies that sponsor research.[49]

The observed multiple views of articles suggest small pockets of common interest in a given study among the health personnel. As noted of the six articles that were viewed more than 20 times, only one (16%) was available to the public without a paid subscription. This roughly approximates the overall state of public access to the scholarly literature, which was calculated to be just over 20% for the entire scholarly output and 18.6% specifically for medicine in 2009.[5]

Twenty percent of the articles accessed by health personnel in 2011 were published in 2011, supporting previous findings that health personnel tend to access the most current literature in patient care.[50] The NIH Public Access Policy, which allows publishers to impose a one-year delay between publication and public access through PMC, could be problematic given this policy and create a disparity between health personnel working in medical centers affiliated with a well-funded library and those who do not. Since the adoption of the NIH Public Access Policy in 2008, there have been calls for adjusting this 12-month requirement to six months to match the pace of scientific research and the policies of the European Research Council,[10] the Wellcome Trust (UK)[11] and the Canadian Institute of Health Research[12]. The results of the current study strongly support reducing this waiting period to six months or less.

That 20% of the journals accessed accounted for 88% percent of the articles accessed somewhat aligns with the 80/20 principle, which has been adopted as a means of better understanding the utilization of library collections.[51] However, the data collected here also suggests that a wide range of journals are consulted by those involved in clinical care including journals from the professional domains of medicine, nursing, social work and occupational health. Similar to reported reading habits of researchers, these health personnel accessed a wide range of works based on search strategies and targeted areas of interest.[52] Our study results underline how important it is for libraries to provide access to highly cited titles, but also indicates the need to maintain a broad library collection to satisfy the diverse needs of health personnel.

As exemplar stewards of knowledge,[53] librarians routinely monitor information access by surveying patrons, tracking online journal use, etc. to inform the maintenance and the evolution of library collections, Although valuable, these data are generally at the resource level and lack the granularity of the article level access that is essential to evaluating the impact of science policy, such as the NIH Public Access Policy. Therefore, we suggest that librarians consider modifying current practices to examine information use at the article level via web logs in order to better understand patron use habits and inform science policy based on solid evidence. For example, use of web logs enables the determination of the publication dates of articles accessed, which can inform policy maker's decisions related to open access embargoes. Additionally, web log analysis can surface governmental funding source information, which can inform the spread of public access policies to government agencies beyond the NIH.

Limitations of the study

The data analyzed in this study represent traffic through UpToDate and PubMed via Lane Library on the SUH network. Because health personnel information access not originating or passing through Lane Medical Library's online resources or originating outside the hospital were not counted article views may be under-reported. Future studies should consider designing and implementing mechanisms to capture a broader array of user data.

This study focuses on health personnel access of research evidence and cannot draw conclusions as to the amount of reading done or to the utility of the accessed information for application to patient care. For example, although the collected data indicate that a particular clinical trial was accessed, we are unable to determine if that study was read or applied in any fashion to patient care. Additionally the methodology is unable to provide records with regard to the access of individuals or groups, making it impossible to identify if perhaps a single user or a particular group was responsible for particular information access patterns. As a further step in this direction, several of the authors of this study are undertaking an RCT with physicians, assessing changes in their information-seeking behaviors when provided with relatively complete access, with more detailed analysis of the value and contribution this information makes to their clinical care.[54] As a limitation of the study's methodology it was not possible to determine whether or not an article was in PMC, and therefore freely available, at the time of its access. This inability stems from the fact that the study retrospectively queried for article metadata to determine the presence of PMCIDs. For example, an article accessed in January 2011 may or may not have been in PMC at that time, even though a PMCID was present in March 2012. Future researchers should consider this a factor in their study design and check for the presence of PMCID immediately after access so as to be able to accurately determine the PMC status of the accessed article.

In addition, the results may overestimate article views for clinical care, as use sometimes may have been for research purposes instead of patient care. However, SUH's mission statement begins by asserting its dedication to the care of patients,[28] which we propose would be similar to the missions of most healthcare facilities. Related to health personnel's tendency to access current information it is important to consider the potential impact of PubMed's design, which by default is set to return current results first. This default may bias use toward more recent literature.

Conclusion

At SUH, health personnel use PubMed and UpToDate to varying degrees with UpToDate being used almost more than twice as often as PubMed in clinical care. Although both resources serve as gateways to journal articles, UpToDate was rarely used in this capacity whereas PubMed was frequently used to access journal articles. When accessing journal articles from either resource, health personnel tended to access review articles and clinical trials. Accessed journal articles also tended to be published within the last ten years and were drawn from a large number of journals across a variety of disciplines. These findings have implications for library collection development and science policy, specifically related to embargo periods, such as included in the NIH Public Access Policy. While there are limitations to this study, this is a first step in investigating information access by health personnel. We hope that it will inspire other similar assessments of information use to build a more reliable estimate of health personnel access to the biomedical literature in order to inform science policy and collection development.

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CHAPTER 4

Evidence based medicine training in undergraduate medical education: A review and critique of the literature published 2006–2011

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Evidence based medicine training in undergraduate medical education: A review and critique of the literature published 2006–2011. *Academic Medicine*. (2013). 88(7):1022-1028.

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Abstract:

To characterize recent evidence-based medicine (EBM) educational interventions for medical students and to suggest future directions for EBM education. The authors conducted searched the MEDLINE, Scopus, Educational Resource Information Center, and Evidence-Based Medicine Reviews databases for English-language articles published between 2006 and 2011 that featured medical students and an intervention addressing multiple EBM skills. They extracted data on learner and instructor characteristics, educational settings, teaching methods, and EBM skills covered. The 20 included articles described interventions delivered in 12 countries in classroom (75%), clinic (25%), and/or online (20%) environments. The majority (60%) focused on clinical students, while 30% targeted preclinical students and 10% included both.. EBM skills addressed included recognizing a knowledge gap (20%), asking a clinical question (90%), searching for information (90%), appraising information (85%), applying information (65%), and evaluating practice change (5%). Physicians were most often identified as instructors (60%); co-teachers included librarians (20%), allied health professionals (10%), and faculty from other disciplines (10%). Many studies (60%) included interventions at multiple points during one year but none was longitudinal across the student's tenure. Teaching methods varied. Intervention efficacy could not be determined. Settings, learner levels and instructors, teaching methods, and covered skills differed across interventions. Authors writing about EBM interventions should include detailed descriptions and employ more rigorous research methods to allow others to draw conclusions about efficacy. When designing EBM interventions, educators should consider trends in medical education (e.g., online learning, interprofessional education) and in health care (e.g.,patient-centered care, electronic health records).

Although evidence-based medicine (EBM) has been included in undergraduate medical education (UGME) for more than 20 years,[1] many physicians and residents lack the knowledge and skills to incorporate evidence into practice[2]. EBM is the judicious use of the best current evidence in making decisions about the care of individual patients[3] and has been linked to reduction of medical errors, promotion of individualized care, and increased application of best practices.[4,5] Since the concept of EBM was introduced in 1991,[5] it has been adopted by medical schools worldwide. Competence in EBM (also known as evidence-based practice) is now required by many health profession organizations for licensing and certification purposes.[6]

Today most medical schools include EBM in their curricula,[6,7] but its implementation is not standardized.[8-10] For example, EBM may be introduced in the first year at one institution[11] but in the final six weeks at another.[7]It is taught using a wide variety of methods and settings, ranging from online instruction[8] to bedside teaching.[12] Furthermore, while many institutions focus on some combination of the traditionally defined steps of EBM—formulating a clinical question, searching the literature, critically appraising found literature, and applying evidence to patient care[13]—they stress certain domains and pay less attention to others.[14]

We conducted this literature review to characterize educational initiatives targeting the improvement of medical students' EBM skills. After our preliminary review of PubMed citations dating back to the early 1990s revealed rapid advances in technology that have modified the practice and teaching of EBM, we decided to focus on studies published 2006–2011 in order to present examples of EBM interventions relevant to the current educational environment. We limited the review to interventions at the UGME level to explore how physicians first acquire basic EBM skills. After providing an overview of UGME interventions, we suggest future directions for EBM in the contexts of medical education and health care based upon our findings and our experience with EBM education.

Methods

Search strategy and data sources

Using published search-strategy guidelines,[15] one of us (L.M., a medical librarian) searched the MEDLINE (via PubMed), Scopus, Educational Resource Information Center (ERIC), and Evidence-Based Medicine Reviews (EBMR) databases using a combination of National Library of Medicine medical subject headings (MeSH) and keyword variants, including *evidence-based medicine; EBM; evidence-based practice; EBP; students, medical; education, medical, undergraduate; education; training; teaching; curriculum;* and *workshops*. The initial searches were run on November 17, 2011, and were limited to English-language articles focusing on UGME published since January

1, 2006. These searches were rerun on June 6, 2012, to capture articles published through the end of 2011. To ensure comprehensive retrieval, L.M. cross-checked the database searches by hand searching relevant medical education journals (*Academic Medicine*, *Teaching and Learning in Medicine*, *Medical Teacher*, *Medical Education)* and the reference lists of all papers selected for full-text review. (The full search strategies are available from L.M. upon request.)

Inclusion and exclusion criteria

We considered studies that included (a) medical students, defined as students in MD training programs, and (b) an EBM educational intervention, defined broadly as instruction designed to improve students' understanding of EBM and to enhance their EBM skills. We excluded studies that only focused on a single EBM skill (e.g., literature searching) because we felt such interventions were narrow in scope and did not address EBM holistically. We also excluded studies that only evaluated existing EBM knowledge, skills, or attitudes, as they did not feature an intervention. In the two instances in which an intervention was described in multiple articles, we selected the article that provided the most complete description for analysis[7,16] and excluded the other.

Title and abstract review

Two of us (L.M., N.T.) independently reviewed all titles and abstracts of articles identified through the database searches to select studies for full-text review. If these authors disagreed on an article's eligibility, the article was included in the set for full-text review.

Data extraction and full-text review

To facilitate our full-text review of articles, we created a modified version of the Best Evidence in Medical Education (BEME) data extraction tool for systematic reviews.[17] This was available to all of us online via the Qualtrics[18] survey tool and enabled us to collect information on:

- educational settings (classroom, clinical, online),
- study participants: instructor type (e.g., physician, librarian), and learner level (pre-clinical, clinical, both),
- EBM skills covered (four traditional steps[13] plus recognizing a knowledge gap and evaluating the change in practice), and
- teaching methods used.

We defined classroom settings as traditional classrooms, conference rooms, ward-based team rooms, lecture halls, and computer labs. We defined clinical settings as environments within the context of clinical care (e.g., bedside rounds).

To evaluate the quality of the EBM interventions, we used Kirkpatrick's hierarchy,[19] which describes the impact of a training intervention based upon the level of learning achieved. To characterize teaching methods, we used Khan and Coomarasamy's hierarchy[20] of EBM teaching and learning methods, which describes three levels of interactivity and integration with clinical activities.

Two of us independently reviewed the full text of each article: L.M. reviewed all articles whereas the rest of us (N.T., B.O., O.tC., C.C.) each reviewed a quarter of the total articles. We completed our reviews using the data extraction tool. Any differences in data extraction were resolved through discussion between L.M. and the other author who reviewed the relevant article.

Data synthesis and analysis

We used Qualtrics[18] to generate summary reports and descriptive statistics to characterize the educational interventions. Through this process, we determined that, due to the lack of rigor in the study design and methodology of the included articles, it was not possible to draw conclusions about the effectiveness of the interventions. Therefore, we excluded classification by Kirkpatrick's hierarchy[19] from our analysis.

Results

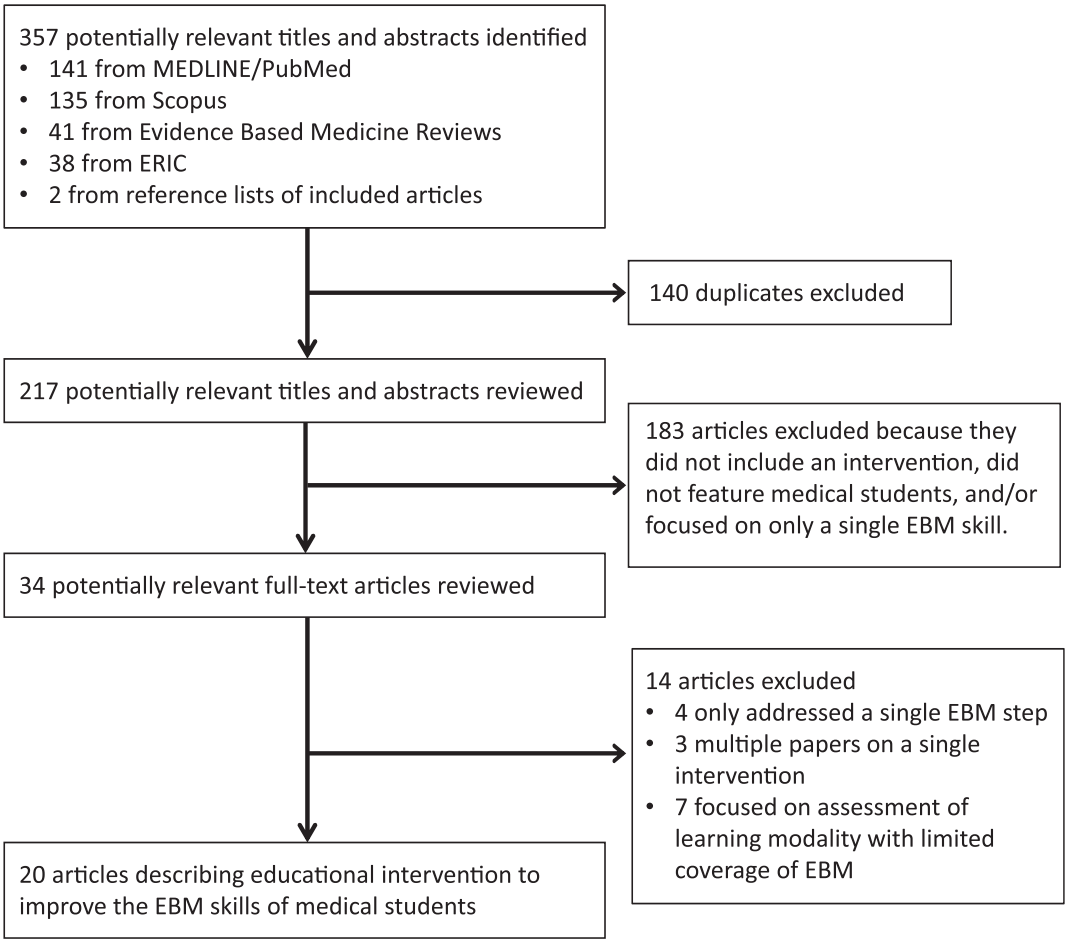
Our database and hand searches identified 357 articles. After excluding duplicates, we reviewed the titles and abstracts of the remaining 217 articles and determined that 34 studies met criteria for full-text review. Fourteen were excluded following full-text review, leaving us a final sample of 20 articles[7-10,16,21-35] (See figure 1 and appendix 1).

Educational settings

These 20 studies presented a global sample of interventions and included 7 (35%) from the United States, 2 (10%) each from the United Kingdom and Thailand, and 1 (5%) each from Australia, China, Czech Republic, Iran, Japan, Jordan, Malaysia, Nigeria, and Pakistan. All described an EBM educational intervention at a single institution, with the exception of one[30] that included two institutions in the United Kingdom.

EBM instruction was delivered in classroom, clinical, and online environments, or a combination of settings. Most interventions (n = 15; 75%) included classroom instruction, while 8 (40%) involved clinical settings (e.g., bedside rounds). Three interventions (15%) included online environments; one of these was completely online.[30]

Figure 1: Literature search and study selection process in a review of evidence-based medicine educational interventions in undergraduate medical education, published 2006–2011.



Study participants

Learner levels

Interventions targeted medical students at all years of study. Six interventions (30%) were aimed at preclinical students, whereas 12 (60%) focused specifically on clinical students. Two (10%) of the interventions[16, 35] included both preclinical and clinical students, and one (5%) included clinical, nursing, and pharmacy students.[25]

Seven (58%) of the 12 interventions focused on clinical students were integrated into clerkships. Five studies named specific clerkships—pediatrics,[7,27,28] family medicine,[32] and internal medicine[31]—while two[8,33] indicated that EBM interventions were implemented across all clerkships. The other 5 clinical-level interventions were standalone courses or workshops.

Instructors

We were not able to determine the instructor's profession from the descriptions provided in 8 (40%) of the included studies, including the online-only intervention.[30] All 12 (60%) of the articles that provided this information identified physicians as instructors, and more than half of these interventions (n = 7) also included collaborating librarians,[21, 26, 28, 32] medical educators,[35] business school faculty,[29] or nurses and pharmacists.[25] Residents served as instructors in one intervention.[7] Six (30%) of the included studies described faculty development initiatives related to the EBM intervention, ranging from faculty being provided the workshop materials that would be distributed to the students[34] to a half-day EBM workshop.[33]

EBM skills addressed

Each study described an intervention that addressed a combination of EBM skills: recognizing a knowledge gap (n = 4; 20%), asking a clinical question (n = 18; 90%), searching for literature (n = 18; 90%), appraising evidence (n = 17; 85%), applying evidence to patient care (n = 13; 65%), and evaluating the change in practice (n = 1; 5%).

Although none of the interventions addressed all six skills, 5 (25%) covered five skills. Four of these—such as the intervention for preclinical students described by Nieman et al[26] that included a two-hour workshop and the completion of EBM assignments during pre-clinical preceptorship activities—did not address the skill of evaluating changes in practice. While Liabsuetrakul et al[10] did address evaluating changes in practice in the longitudinal classroom-based EBM course they implemented across two years of their institution's curriculum, they did not include activities related to recognizing knowledge gaps. Eleven (55%) interventions addressed the four traditional EBM steps introduced by Strauss[13]: ask, acquire, appraise, and apply.

Teaching methods

Five (25%) of the articles described a one-time educational intervention, such as a three-hour workshop designed to improve clerkship students' clinical question formulation and literature search skills.[31] Twelve (60%) included a series of interventions occuring over a single year. For example, Aronoff et al[8] described a year-long EBM course that included several sessions delivered concurrently with the first clinical year. None of the studies included longitudinal EBM curricula taught across the student's entire tenure, but 3 (15%) described interventions implemented

across more than one year.[10,16,35] For example, West et al[16] reported on a formal EBM curriculum that students begin in their second preclinical year and conclude in their third clinical year. We identified only one other intervention[35] that trained students at both the preclinical and clinical levels.

Using Khan and Coomarasamy's three-level hierarchy of EBM teaching and learning methods,[20] we determined that 8 (40%) of the 20 interventions used level 1 (interactive, clinically integrated), 8 (40%) used level 2 (interactive, classroom-based or didactic, but clinically integrated), and 4 (20%) used level 3 (didactic, classroom-based or standalone) methods. Aronoff and colleagues[8] provided an example of level 1 methods in their description of a multi-part EBM course that included online instructional modules and formalized activities generated from students' formulating their own clinical questions based upon their clerkship experiences.

Discussion

Physicians' failure to engage in EBM has repercussions for the health of individuals and populations.[4,5] It is therefore essential that medical students receive foundational training in EBM. To provide medical educators with an overview of current EBM training, which has become a common topic covered in medical education[36] we reviewed 20 recent studies describing a range of educational interventions taught in a variety of settings and aimed at students at all levels of UGME. Among these interventions, we identified an emphasis on the skills of forming clinical questions, searching the literature, and appraising evidence critically. Our findings suggest there is a need for broader, more comprehensive EBM training, especially in the domains of recognizing a knowledge gap and evaluating changes in practice.

As the reviewed studies lacked robust outcome measures, it was not possible to determine the efficacy of interventions. Therefore, we consider our findings within the broader contexts of UGME and health care. Then, based upon evidence from the reviewed literature and our professional experience—as a physician, as medical educators, and as medical librarians—we offer recommendations for modifying current EBM training.

Implications and recommendations for UGME

Timing of EBM instruction

There is little evidence as to the most efficacious timing for EBM instruction.[37] Yet, our review confirms earlier findings that most EBM educational interventions take place in the clinical years of medical school.[38,39] This timing is generally based on the rationale that the clerkship setting enhances the clinical relevance of the training.[40] However, the trend toward providing students with early clinical experiences[41] may provide opportunities for introducing EBM earlier, in the context of patient care in the

preclinical years. For example, one study demonstrated that first-year medical students who received EBM training prior to a primary care preclinical preceptorship reported increases in self-efficacy and a likelihood that they will continue to use EBM.[26] We suggest that medical educators consider integrating EBM instruction into early clinical experiences, as doing so may increase students' self-efficacy and provide a framework that helps students deal with the uncertainty of being new to the clinical setting.

Longitudinal EBM training

While multiple exposures to EBM training were common in the studies reviewed, longitudinal curricula were lacking. In 75% of the included interventions, medical students received EBM training on more than one occasion, a practice that has been linked generally with increased learning.[42] Yet most of the interventions were delivered over short, intensive time periods. The compressed nature of these learning opportunities limits medical educators' ability to successively build EBM skills across levels of student development. In a spiral curriculum[43]—a format that has been adopted to teach some components of medical education—learners are provided multiple, successive exposures to a concept at different levels of their development so that each encounter builds on the previous encounter.[44] We suggest that integrating EBM training as a spiral curriculum across all levels of UGME may be an effective model.

Interprofessional approach

We identified only one intervention that included both medical students and learners from other health professions.[25] Given the trend in medical education toward recommending the use of interprofessional education (IPE)[45] and the adoption of evidence-based practice by a spectrum of allied health professions, we encourage medical educators to consider taking an IPE approach to EBM instruction. Teaching EBM in an IPE environment could expand students' exposure to a variety of discipline-specific, evidence-based resources and provide them with insight into the ways in which learners and professionals in other fields cope with uncertainty.

Related to IPE, we found several interventions that were taught by both physicians and instructors from other disciplines. Some included medical librarians, whose participation has been shown to add authenticity to EBM training.[28] Of note, one intervention[29] reached beyond the medical school's resources to integrate business school faculty, who shared their expertise in change management techniques and organizational behavior. We recommend that medical educators consider including instructors from a variety of disciplines and think beyond the classroom setting when integrating multidisciplinary teachers. For example, all of the interventions that involved medical librarians as instructors were set in classrooms. A classroom-based approach, however, does not enable clinical librarians, who have been working at the point of care for over 30 years,[46] to demonstrate real-time information retrieval and interprofessional collaboration.

Active and online learning environments

Recently, Prober and Heath[47] declared, "It's time to change the way we educate doctors," and advocated a shift from a lecture-based format to an active learning approach that blends online learning with more-interactive classroom activities, such as case studies.[47] We found that EBM interventions for medical students are already using interactive teaching methods and online learning. Three interventions[28,30,32] employed an online format to decompress classroom time, extend the reach of strained faculty resources, mitigate scheduling difficulties, and/or reach students at diffuse clinical sites. As online instruction—which has been shown to be as effective as in-person instruction for EBM[32,48]—continues to evolve, we suggest that educators look for opportunities to increase the use of online components in EBM curricula.

Gaps in knowledge

Finally, medical educators have dedicated much attention to the physician's ability to self-monitor, that is, to recognize the limitations of one's skill and knowledge to act in a specific situation.[49,50] In the context of EBM, this self-monitoring connects with the practitioner's ability to recognize gaps in his or her knowledge, which has been dubbed "step zero" in evidence-based practice.[51] Being able to identify awareness of a knowledge gap is critical, as doing so acts as the fuel that ignites the EBM process and prompts the physician to ask clinical questions and proceed through the subsequent steps. Yet while 90% of reviewed interventions addressed the mechanics of asking a clinical question, only 20% addressed the necessary precursor of identifying knowledge gaps. For example, one intervention[26] challenged students to identify and record at least four knowledge gaps generated by encounters with patients. Based on our review findings, and research showing that physicians tend to be weak in recognizing when they have clinical questions,[52] we suggest that all EBM training should cover the essential skill of recognizing a knowledge gap.

Implications for health care and related recommendations

Patient-centered care

In the Patient Protection and Affordable Care Act of 2010, the United States committed funding to support patients and clinicians in making shared, evidence-based decisions[53]. Although a handful of included interventions[7,8,16,28,29,33] required students to generate clinical questions based on their patient encounters and contemplate how they might apply evidence to patients' care, none included training on discussing evidence with patients. We suggest that medical educators consider how to provide opportunities for students to engage in sharing evidence with patients to facilitate decision-making activities.

The related scenario of the patient as the bearer of evidence was also absent from the reviewed interventions. Recent research has demonstrated that physicians "experience considerable anxiety in response to patients bringing information from the internet

to a consultation,"[54] which suggests that this is an area ripe for improvement. As it is probable that patients will increasingly bring information to appointments, we recommend that medical educators train students to evaluate the evidence retrieved by patients and to engage in productive conversations in which the student and patient can reflect on the information and, if appropriate, integrate it into the patient's care.

Electronic health records

While all of the reviewed interventions included instruction on how to search the literature using traditional resources (e.g., PubMed), none addressed how to access information via electronic health records (EHRs). EHRs are becoming increasingly prevalent in medical practice and their capabilities are improving with regard to delivering information and prompting clinical questions within the workflow via alerts and "infobuttons."[55] Educators therefore need to ensure that EBM training accommodates these evolving resources. For example, they may need to shift emphasis from PubMed search skills to information management skills, such that students learn to manage or triage point-of-care information presented within EHRs. Additionally, educators should seize the opportunity to use EHRs to facilitate EBM teaching. For example, students could be asked to summarize any information they consulted in caring for a patient and attach the summary to the patient's EHR. This would provide students with authentic EBM opportunities and also broaden the evidence base of all health professionals who interact with the patient's EHR.

The increasing use of EHRs may also expand the types of available evidence.. Recently, a physician team at Stanford was temporarily stymied by the lack of published evidence related to the treatment of a complicated pediatric case. However, by querying the EHR system, they identified a cohort of similar patients and analyzed outcomes data to make an informed treatment decision.[56]Although this is currently considered a "novel" process, such use of EHR data is likely to become increasingly prevalent. We therefore recommend that medical educators expand the coverage of searching the biomedical literature to include querying EHRs.

Limitations

This review must be considered in the context of its limitations. We only captured descriptions of UGME interventions that targeted multiple EBM skills and were published during 2006–2011. It is also possible that there are institutions that have robust EBM education programs but have not published studies on these programs. Further, we were not able to judge the strength of the interventions and make recommendations accordingly.

Conclusions

Given the importance of EBM to providing high-quality patient care and widespread application of this approach across health professions, it is surprising that UGME training programs for EBM skill development have not been well described in the literature. Better descriptions of interventions and more rigorous research methods are needed so that educators and researchers can draw conclusions about the efficacy of interventions and, if so desired, replicate them. We encourage educators to consider designing EBM interventions that are in alignment with major trends in medical education and health care, including IPE, EHRs, and patient-centered care, and publishing their findings.

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Appendix 1: Descriptions of 20 educational interventions to improve undergraduate medical students' Evidence-Based Medicine (EBM) skills and understanding, published 2006–2011.

Study [ref. no.]	Location	Learner level	Instructor type*	Setting	Level in Khan and Coomarasamy's hierarchy †	EBM skills addressed ‡
Aronoff et al, 2010 [8]	United States	Clinical	Faculty unspecfied	Clinical	1	1, 2, 4
Chakraborti, 2011 [21]	United States	Preclinical	Faculty unspecified, librarians	Classroom	2	1, 2, 3
Iqbal and Zaidi, 2009 [22]	Pakistan	Clinical	Physicians	Classroom	3	1, 2
Johnston et al, 2009 [9]	China	Preclinical	Faculty unspecified	Classroom	2	0, 1, 2, 3, 4
Khader et al, 2011 [23]	Jordan	Preclinical	Unable to determine	Classroom	2	1, 2, 3, 4
Lai and Teng, 2011 [7]	Malaysia	Clinical	Residents	Clinical	1	1, 2, 3, 4
Liabsuetrakul et al, 2009 [10]	Thailand	Preclinical	Physicians	Clinical	2	1, 2, 3, 4, 5
McMahon and Dluhy, 2006 [24]	United States	Preclinical	Unable to determine	Classroom	2	1, 3
Nango and Tanaka, 2010 [25]	Japan	Clinical; also nursing and pharmacy	Physicians, nurses, pharmacists	Classroom	1	1, 2, 3, 4
Nieman et al, 2009 [26]	United States	Preclinical	Physicians, librarians	Classroom	1	0, 1, 2, 3, 4
Okoromah et al, 2006 [27]	Nigeria	Clinical	Faculty unspecified	Classroom	2	1, 2, 3
Potomkova et al, 2010 [28]	Czech Republic	Clinical	Physicians, librarians	Clinical, online	1	1, 2, 3, 4
Rhodes et al, 2006 [29]	United Kingdom	Preclinical	Physicians, business school faculty	Classroom, clinical	3	0, 1, 2, 3, 4
Sandars et al, 2010 [30]	United Kingdom	Clinical	Unable to determine	Online	3	4
Sastre et al, 2011 [31]	United States	Clinical	Physicians	Classroom	3	1, 2, 3
Schilling et al, 2006 [32]	United States	Clinical	Physicians, librarians	Clinical, online	1	1, 2
Stockler et al, 2009 [33]	Australia	Clinical	Physicians	Clinical	1	0, 1, 2, 3, 4
Taheri et al, 2008 [34]	Iran	Clinical	Physicians	Classroom	2	1, 2, 3
Wanvarie et al, 2006 [35]	Thailand	Preclinical, clinical	Physicians, medical educators	Classroom, clinical	1	1, 2, 3, 4
West et al, 2011 [16]	United States	Preclinical, clinical	Physicians	Classroom, clinical	1	1, 2, 3, 4

Appendix 1: Notes

* Articles that did not provide any details of instructor identity are labeled "unable to determine." Those that reference faculty members as instructors but provide no further details are labeled "faculty unspecified."

† Khan and Coomarasamy's[20] hierarchy of EBM teaching and learning methods includes the following levels:

level 1 (interactive, clinically integrated)

level 2a (interactive, classroom based)

level 2b (didactic, but clinically integrated)

level 3 (didactic, classroom based, or stand-alone).

Here, "2" indicates an intervention that employed either level 2a or 2b methods.

‡ EBM skills addressed in each intervention are coded as follows:

0 = recognizing a knowledge gap

1 = asking a clinical question

2 = acquiring information

3 = appraising information

4 = applying information to patient care

5 = evaluating change in practice

CHAPTER 5

Challenges to learning Evidence-Based Medicine and educational approaches to meet them: A qualitative study of selected EBM curricula in North American medical schools

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Challenges to learning Evidence-Based Medicine (EBM) and educational approaches to meet these challenges: A qualitative study of selected EBM curricula in U.S. and Canadian medical schools. *Academic Medicine*.

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Abstract

Evidence-based medicine (EBM) is a fixture in many medical school curricula. Yet little is known about challenges medical students face in learning EBM or educational approaches that medical schools use to overcome these challenges. Knowledge of these challenges and approaches can facilitate the design of EBM training. A qualitative multi-institutional case study was conducted between December 2013-July, 2014. Based on Association of American Medical Colleges 2012 Graduation Questionnaire data, the authors selected institutions with graduates reporting confidence in their EBM skills. Thirty-one EBM educators (17 clinicians, 11 librarians, 2 educationalists and 1 epidemiologist) were interviewed from these institutions (13 in the United States; 4 in Canada) and requested they submit curricular materials. Participants were asked to describe EBM learning challenges and describe their EBM curriculum. Interviews were recorded, transcribed and analyzed. Institutional profiles were created for each institution including details of their EBM curriculum and identified student challenges. The authors identified common educational approaches that the institutions used to meet these challenges. EBM learning challenges include: sub-optimal role models, student lack of willingness to admit uncertainty, lack of clinical context and difficulty mastering EBM skills. Educational approaches to these challenges include: integration of EBM skills with other content/courses, incorporation of clinical content, faculty development, use of whole-task activities and longitudinal integration of EBM. The identification of these four learner-centered challenges expands upon the available literature on barriers to learning EBM. The five educational approaches provide potential strategies for medical educators to inform their EBM training.

In the last twenty years, Evidence Based Medicine (EBM) has become a standard component of medical school curriculum.[1] Despite its ubiquitous inclusion, physicians' practice of EBM is suboptimal,[2-4] which has implications for patient safety, cost effectiveness and consistency of care.[5,6] This suboptimal practice of EBM has prompted researchers to explore challenges to physicians practicing, clinician educators teaching, and students learning EBM.

In clinical practice, research on barriers to practicing EBM has identified challenges reported by physicians such as lack of time, conflicts between evidence-based recommendations and patient preferences and weak available evidence.[4,7] Additionally, EBM instructors have described barriers to teaching EBM in clinical care. These barriers include lack of time available for teaching EBM, the absence of EBM requirements for trainees and the lack of their own and trainees' EBM knowledge and skills.[8] Based on these studies, researchers have suggested that practitioner challenges be considered when designing student EBM training as they may have implications for student learning. For example, if physicians are challenged by time constraints and fail to practice EBM then students may have limited exposure to positive EBM role models, which could impact their learning experiences. Although research on these barriers may inform student training it does not directly examine challenges that medical students may face when learning EBM, which may differ and contribute to the suboptimal practice of EBM.

Research on challenges for students learning EBM is limited and focused on training in clerkship settings. For example, two studies described student challenges including, receiving minimal support from clinical teachers for using EBM and limited opportunities for practicing EBM in clerkships.[9,10] Knowledge of these challenges in clerkships is important, but narrow in scope, as EBM training can be offered across all years of medical school.[11] Additionally researchers have studied barriers that faculty perceive in implementing EBM curricula.[12-14] However, these studies focus on barriers to delivery such as lack of curricular time.[13]

Our study aims to identify challenges that medical students face across medical school when learning EBM. With these barriers identified, we then explore potential solutions by examining ways in which some medical schools' EBM curricula have overcome these barriers. Thus, our study aims to identify and describe educational approaches for teaching EBM used by medical schools identified as graduating students who feel confident in their EBM abilities.

Methods

We conducted a qualitative multi-institutional case study between December 2013 and July, 2014. We selected this approach to gather in-depth information about how medical schools teach EBM and the challenges they perceive students face in learning EBM. Stanford University's Institutional Review Board deemed this study exempt.

We used purposive criterion sampling[15] of medical school curricular deans. To generate the sample, LAM requested the names of 22 medical schools in the United States (US)(n=17) and Canada (n=5) from the Association of American Medical Colleges based on 2012 Graduation Questionnaire data. US schools were selected if more than 50% of graduating students expressed confidence in their basic skills in clinical decision-making and application of evidence based information to medical practice. Canadian schools were selected if more than 25% of students felt confident they had the knowledge and skill to incorporate evidence-informed decision making into patient care. We selected this sample based on the premise that institutions graduating students satisfied with their EBM abilities may have noteworthy educational approaches for teaching EBM. None of the authors were affiliated with the included institutions.

Via email, LAM invited the curricular dean from each institution to be interviewed, or if appropriate, to forward the invitation to the individual they believed was most knowledgeable about EBM instruction at their institution. Deans received up to three reminders and if still not responsive, LAM searched the institution's website to identify faculty involved in EBM and contacted them directly. If this second strategy failed, the institution was excluded. During interviews, several participants recommended contacting others involved in EBM at their institutions. LAM invited the recommended individuals to participate. We interviewed faculty instead of students because they would be most knowledgeable about the design and delivery of their curriculum. Additionally, we felt that over time faculty would have observed how students experienced challenges in learning EBM and how their curriculum may or may not have helped students overcome those challenges.

Using a semi-structured interview protocol, LAM interviewed all participants via telephone in January and February 2014. Before the interview, participants were e-mailed the protocol. The protocol asked participants to describe their approach to designing the EBM curriculum that their 2012 graduates would have experienced and to identify elements of learning EBM that students find challenging and how they address these challenges (Appendix 1). The protocol was designed based on the biomedical literature and contributions from the multi-disciplinary authors, including educators, physicians and a librarian familiar with EBM. The interview protocol was pilot tested with EBM instructors at two institutions not in our sample. Minimal

refinements were made based on pilot and author feedback. All interviews were audio-recorded and transcribed. Prior to the interview and if necessary at its conclusion, participants were requested to provide EBM curricular materials, such as syllabi, slides and assignments.

Our study used an inductive approach to data analysis in an attempt to keep our findings consistent with what participants said regarding student learning challenges and educational approaches. To begin LAM and BCO familiarized themselves with all transcripts through multiple readings. During this familiarization process, they identified preliminary common student-learning challenges, which they captured in brief analytic memos to facilitate discussions.[16] Following discussions based on the transcripts and collected EBM curricular materials, LAM created profiles of each institution's EBM curriculum. The profiles included a working list of educational approaches derived from the transcripts that potentially addressed the identified student challenges. Participant transcripts, institutional profiles and the working list of educational approaches were shared with BCO and HCC to independently revise and, if appropriate, confirm the challenges and educational approaches identified. BCO and HCC each reviewed six institutions. LAM reviewed all 17 institutions. The co-authors met to review the materials and consensus was reached via discussion on the identified challenges and educational approaches.

Results

We interviewed 31 EBM educators from 17 medical schools in the US (n=13) and Canada (n=4). Five schools were not included due to lack of response. Although initially designed to focus on curricular deans, 13 deans referred us to other educators. Overall we interviewed clinicians (n=17 of which four were curricular deans), librarians (n=11), educationalists (n=2) and an epidemiologist (n=1). Thirteen institutions shared curricular materials, including syllabi, slides and assignment guides.

Although these institutions graduated students confident in their abilities to practice EBM, participants reported that their students face a variety of challenges when learning EBM. We identified four common challenges: sub-optimal role models, student lack of willingness to admit uncertainty, lack of clinical context and difficulty mastering EBM skills.

Sub-optimal role models were the most identified student learning challenge. Participants were concerned that due to role models exhibiting poor attitudes towards EBM, weak EBM skills and a disinclination to make explicit their "invisible EBM process" (D), that students experience a disconnect between what they were being taught in the EBM curriculum and what they were witnessing in clinical settings. Participants underscored the need for faculty role modeling EBM due

to an overwhelming concern that that students' EBM training could be readily "extinguished" (I) if learners fail to see EBM practiced.

Participants reported students' lack of willingness to admit uncertainty as an EBM learning challenge. They felt that this caused learners to avoid EBM, which requires as its first steps recognizing and articulating uncertainty as a clinical question. Some participants felt that students' lack of willingness to admit uncertainty was reinforced by faculty not role modeling EBM, especially not voicing their uncertainty in clinical care. "It's a rare teacher who is verbalizing everything they're thinking. It's a rare teacher who will say, 'I don't really know why we do what we do' or 'I don't know what to do here"(E).

Several faculty identified students' lack of clinical context as a challenge to learning EBM, especially in the preclinical years. They felt that without clinical context, students struggled to view EBM as equally important to other content and noted that students failed to appreciate the relevance of EBM to physicians' work.

Several faculty members also mentioned students' difficulty mastering EBM skills. All core EBM skills were identified as challenging, especially application of evidence to patient care. Participants felt students struggled to use evidence in making patient care decisions.

Institutions used a variety of educational approaches to overcome these learning challenges, including integrating EBM with other courses/content, incorporating clinical content into EBM training, faculty development, use of whole-task activities and longitudinal integration of EBM. In some instances, multiple approaches were utilized to address the challenges as indicated in Table 1.

Table 1: Learning approaches to address challenges to learning EBM

	Sub-optimal role models	Lack of willingness to admit uncertainty	Lack of clinical context	Difficulty mastering EBM skills
Integration with other content and courses	✓		✓	
Incorporation of clinical content	✓		✓	
Faculty Development	✓	✓		
Use of whole-task activities		✓	✓	✓
Longitudinal integration of EBM		✓	✓	✓

Integration with other courses/content

EBM was generally not taught as a standalone course. Frequently EBM was integrated into other curricular courses and content to expose students to EBM in the context of related topics, provide opportunities to practice and master EBM skills and increase the relevance of EBM to practicing medicine. "We explicitly weave EBM through our other curricular themes so that it becomes the fabric of our curriculum rather than just a standalone course" (E). Commonly, EBM was integrated into epidemiology and biostatistics sessions, but also community health, clinical exam skills and ethics. For example, one institution when teaching clinical exam skills required students to form questions about the efficacy of diagnostic maneuvers, locate relevant evidence, appraise it and discuss the need to learn the maneuvers for future use. Integration with other courses and content included opportunities for subject matter experts like epidemiologists to role model EBM skills therefore potentially counterbalancing sub-optimal clinical role models that they may observe in practice. Many schools integrated EBM with problem-based learning (PBL) sessions and several schools introduced EBM within the context of PBL clinical cases thus providing students clinical context for EBM. Participants also noted that integration with PBL provided students ongoing opportunities to pose questions therefore increasing comfort with uncertainty.

EBM was also integrated into clerkships, which helped place students' EBM experience in clinical context. Clerkship integration often focused on applying EBM skills to assignments that required students to identify a clinical question based on a patient and undertake the remaining EBM steps. Several institutions also included student-run, EBM journals clubs in clerkships. Most institutions integrated EBM into a single clerkship, but in some cases EBM was featured in several clerkships commonly internal medicine, family medicine and/or pediatrics. One institution incorporated EBM into eight clerkships. This institution utilized an online EBM Education Prescription tool, which captured clinical questions, coached learners through the EBM process and provided a structured interface for instructors to evaluate student submissions. To prepare students and ensure the transfer of skills learned in preclinical sessions, EBM was often integrated into transition to clerkship courses. EBM coverage in transition courses often focused on refreshing EBM skills.

Incorporation of clinical content

Schools incorporated clinical content into EBM curriculum with many emphasizing efforts to present EBM in the context of individual patient problems early and often. One participant described clinical content as "candy" (G) that provided students a context for learning EBM; it raised interest levels and increased the relevance of EBM training. Clinical content generally took the form of patient cases and/or patient-based examples delivered orally, on paper and via video that were often integrated into EBM lectures, small group discussions and assignments. Several institutions included

physicians additionally provided learners exposure to physicians who were positive role models in their approaches to EBM. They often included the "EBM rock stars" (J) of an institution, in-person and/or video-recorded, presenting clinical cases based on their own practice and role modeling their approach to EBM. Due to students' varied levels of clinical exposure and background knowledge and a desire to incorporate clinical content early, institutions were mindful of how EBM was introduced with the majority of schools using a simple to complex approach. Interviewees described providing novices with straightforward patient cases dealing with single, familiar conditions that had been previously addressed in the curriculum or that were under current discussion in other courses. As students progressed, instructors incrementally increased clinical content complexity.

Faculty Development

EBM faculty development initiatives focused on bolstering faculty EBM skills and fostering a "cadre of faculty members that role model EBM practices in their routine care of patients " (L). Therefore, institutions trained PBL facilitators, community preceptors, residents, fellows and clinician educators in hopes that optimal EBM role models would be present throughout a student's training. Faculty development sessions generally covered core EBM skills. Several participants also described efforts to train EBM instructors to be explicit role models in their EBM practice. To meet this goal, instructors were encouraged and trained to "talk out loud about their EBM thinking process" (E) to make EBM transparent to students and provide them mental models of how a clinician might approach clinical uncertainty in practice. Additionally, faculty members were taught to encourage students to recognize uncertainty in their activities and to provide students time to pursue clinical questions in order to increase students' comfort with uncertainty.

Whole-task exercises

Most EBM training programs included whole-task exercises. Whole-task activities challenge students to practice all constituent parts of a complex task in an integrated fashion. In the case of EBM, this translates to an activity that starts with a clinical question and includes all the EBM steps being executed in a cohesive fashion as would occur in practice. This would be in contrast to practicing each EBM step separately. Whole-task exercises were most prevalent in clerkships where students were generally required to identify uncertainty in their practice and carry out the steps of EBM. At the pre-clerkship level, students also completed whole-task exercises. However, these exercises were generally based on paper cases or students would be asked to identify clinical questions based on their own health or of someone they knew. The repeated practice of whole-task activities provided multiple opportunities for students to seek uncertainty and practice EBM therefore increasing their comfort and mastery of EBM skills.

Longitudinal integration

Most institutions integrated EBM longitudinally across all years of medical school with only two schools providing solely preclinical instruction. "It's clearly not a single encounter with the principles of EBM and then that's it. We really cover EBM many different times throughout their four years" (L). Several participants described using a spiral curriculum design in which EBM basics were introduced early, revisited often and increasingly made more complex as students progressed through medical school. As a longitudinal approach bridges both preclinical and clerkship experiences it provides learners with clinical context for practicing EBM and multiple opportunities to master EBM skills. The importance of longitudinal coverage of EBM was underscored for the continuum of medical education. "I need to get medical students to a certain point with EBM. Then in residency we need to take them to the next step and then we need to reinforce it with practicing clinicians " (E). To support the transition from UME to residency two institutions provided fourth-year capstone sessions to reinforce EBM skills.

Discussion

In this study, we identified that when learning EBM skills students are challenged by sub-optimal role models, their lack of willingness to admit uncertainty, lack of clinical context and difficulty mastering EBM skills. These challenges expand upon previously identified challenges which had focused on what makes EBM difficult to practice and to teach[4,8,12-14] instead of what makes EBM difficult for students to learn. This learner-centric approach uncovered new challenges that may provide medical educators additional insights into how students experience EBM training and potentially guide EBM curricular design. To meet these EBM challenges, we identified five educational approaches, which we now discuss in light of available evidence.

Almost all institutions wove EBM into other courses and content. EBM integration has been shown to improve student attitudes towards EBM,[17] increase students' satisfaction with EBM training[18] and raise students' level of EBM knowledge,[19] suggesting that integration is a warranted approach for teaching EBM. Additionally, the integration of EBM into other courses/content may help decompress overall curricular time needed for EBM, which has been identified as a barrier to teaching EBM.[13]

Most institutions incorporated clinical content into EBM training to increase its relevance and connect EBM to clinical care. At many institutions, physicians introduced authentic cases from their experiences and described how they would practice EBM within the context of the case. This think-aloud approach is an example of supportive information that assists learners in carrying out learning tasks by assisting them in the creation of mental models of how clinical uncertainty can be approached and the steps of EBM undertaken.[20]

Several institutions provided faculty development, which is key as faculty who receive EBM training are more likely to provide EBM instruction to trainees and encourage application of EBM skills in practice.[21] In addition to offering EBM skills training, faculty members were encouraged to act as EBM role models explicit in exposing their uncertainty and vocal in describing their use of EBM to students. This supplement to traditional EBM faculty development is important as students regard EBM role models as major enablers to their practice of EBM.[9] Although institutions trained a wide range of instructors in EBM skills, it is possible that students will still encounter sub-optimal role models. Therefore, medical educators have suggested that students be trained to critically assess role models in order to select those worthy of imitation.[22]

Several institutions included whole-task learning activities throughout their EBM curriculum to facilitate students' mastery of EBM skills. Recently use of authentic whole-task learning for the teaching of complex tasks has become popular[23] and applied in teaching medical topics.[24] Researchers have identified that whole-task learning approaches provide learners a holistic model of how to practice EBM and have also been linked to learners increased ability to transfer skills into practice.[20,25] Whole-task learning approaches are the foundation for several instructional design approaches,[26] which may be valuable for medical educators to review in designing future EBM curriculum.

Most schools' EBM training spanned both preclinical and clerkship learning to create a longitudinal experience. The transition from preclinical training to workplace-based clerkships is stressful for students with many medical schools offering transition to clerkship courses to ease learners' entry into the clinical workplace.[27] Several schools integrated EBM training into transitions courses by providing skills-based sessions that revisited core EBM skills. While skills-based training is a common approach in transition courses,[28] researchers have also encouraged medical educators to emphasize self-directed learning approaches in transition courses.[29] We did not identify this self-directed approach offered by EBM instructors in transition courses.

This study describes challenges to students learning EBM and educational approaches used to meet these barriers by a select sample of medical schools. Although the institutions used these educational approaches, we cannot claim that the approaches necessarily enabled the schools to overcome the challenges we described or that the approaches are appropriate for other institutions or applicable to use with other subjects. However, some of the educational approaches are consistent with theories of learning. For example, integrating EBM training into clinical settings aligns with Situated Learning Theory. Situated Learning Theory tightly ties learning with the authentic activity, context and culture in which it takes place.[30] Additionally, the use of whole-task learning activities aligns with instructional design principles utilized by several instructional models, such as the *Four Component Instructional Design* model.[26]

We interviewed representatives from only North American medical schools. Future researchers might interview a more global sample to shed light on additional barriers and educational approaches. We based our sample on self-reported survey data, which was the only broad indicator of satisfaction with EBM training available. Therefore, we cannot draw conclusions about the students' EBM abilities or future EBM practices, which tempers our ability to recommend the identified educational approaches as best practices. Although we focused on student learning challenges we did not interview students, but instead relied on faculty members' perceptions based on their experience of observing students over time. Future studies might directly involve students. We focused mainly on the formal EBM curriculum and less so on the informal curriculum, although aspects of the informal curriculum were identified as challenges. Future researchers might consider exploring the informal curriculum and its potential impact on students learning EBM.

Although EBM has long been a fixture in UME,[1] students continue to face challenges when learning EBM, which may have implications for their future EBM practice. For EBM training to be successfully implemented in UME, it is necessary for medical educators to be aware of these challenges and consider educational approaches for overcoming them. The identification of these four learner-centered challenges expands upon the literature on barriers to teaching and practicing EBM. The five educational approaches provide potential strategies for medical educators that can be used to inform the design of EBM training.

Disclaimer

This material is based upon data provided by the AAMC. The views expressed herein are those of the authors and do not necessarily reflect the position or policy of the AAMC.

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Appendix 1: Interview Guide

1. What is your role in EBM?

2. What do you think makes your graduates particularly confident in their ability to practice EBM and why? Please consider curricular and non-curricular factors.

3. Please describe your approach to designing your EBM curriculum.

4. Which elements of EBM do you feel that students find challenging and how do you address these? In an ideal situation, how would you design EBM training to overcome these challenges?

5. Is there anything else related to EBM at your institution that we have not yet addressed?

CHAPTER 6

Designing evidence-based medicine training to optimize transfer of skills from the classroom to clinical practice: Applying the Four Component Instructional Design Model

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Designing evidence-based medicine training to optimize the transfer of skills from the classroom to clinical practice: Applying the Four Component Instructional Design Model. *Academic Medicine*.

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Abstract

Evidence-based medicine (EBM) skills, while taught in medical schools around the world, are not optimally practiced in clinical environments because of multiple barriers, including learners' difficulty transferring EBM skills learned in the classroom into clinical practice. This lack of skill transfer may be partially due to the design of EBM training. To facilitate the transfer of EBM skills from the classroom to clinical practice, the authors explore one instructional approach, called the Four Component Instructional Design (4C/ID) model, to guide the design of EBM training. Based on current cognitive psychology, including Cognitive Load Theory, the premise of the 4C/ID model is that complex skills training, such as EBM training, should include four components: learning tasks, supportive information, procedural information, and part-task practice. The combination of these four components can inform the creation of complex skills training that is designed to avoid overloading learners' cognitive abilities; to facilitate the integration of the knowledge, skills, and attitudes needed to execute a complex task; and to increase the transfer of knowledge to new situations. The authors begin by introducing the 4C/ID model and describing the benefits of its four components to guide the design of EBM training. They include illustrative examples of educational practices that are consistent with each component and that can be applied to teaching EBM. They conclude by suggesting that medical educators consider adopting the 4C/ID model to design, modify, and/or implement EBM training in classroom and clinical settings.

Evidence Based Medicine (EBM) involves combining a physician's clinical experience and knowledge with the best available research evidence and with the wishes of a patient[1]. Important for facilitating a patient-centered approach to care[2,3] and lifelong learning for physicians,[4] EBM skills are taught in medical schools around the world to ensure the translation of evidence into clinical practice.[5] Yet, the translation of evidence into practice often occurs sub-optimally, due to a constellation of barriers, including systems factors (e.g. lack of time), attitudinal issues (e.g. negative associations with EBM), lack of skills (e.g. inability to locate evidence) and the tacit conviction that EBM may be a less effective approach to care than it was initially thought to be. [6-8] While each barrier is daunting, the reported lack of EBM skills in practice, despite the ubiquity of EBM training, may indicate a weakness in the design of EBM training and may suggest that current training does not optimally enable learners to transfer EBM skills from the classroom to clinical practice. Although there may be a variety of factors that hinder the transfer of EBM skills this article focuses on the structure of EBM training, which researchers have indicated may impede learners' ability to transfer EBM knowledge and skills into clinical practice.[9]

Currently there is no universally endorsed approach to teaching EBM at the undergraduate level.[10] However, methods that focus on teaching discrete elements of EBM in various segments of the medical curriculum are common[11] and have been recommended.[12] We would characterize this as an atomistic approach that introduces each component EBM skill (e.g. asking clinical questions, searching for evidence, critically appraising articles) separately and then, after practicing each skill individually, assumes that learners are able to assemble the steps into a cohesive whole. Using such a step-wise approach to design, faculty members might first teach learners to formulate clinical questions and search the biomedical literature in one session, then train them to critically appraise articles a semester later, and finally require learners to put these skills together to practice the entire EBM process when delivering patient care during clerkship. Atomistic or non-integrated approaches to teaching complex cognitive skills have been associated with fragmentation of learning and lack of skill transfer[13,14] suggesting a need for a modified approach to designing EBM training to ensure transfer.

To practice EBM, physicians must simultaneously integrate clinical knowledge, patient preferences and external evidence to reach patient-centered decisions. This makes EBM a complex task. Complex tasks generally feature multiple solutions, take many sessions of practice to master and generally overload a learner's cognitive system.[15] Complex tasks, including EBM, also require the execution of sub-skills[16] including those that are consistent or recurrent from scenario to scenario (e.g. calculating a number needed to treat) and those that are non-recurrent, varying between situations, such as applying the evidence to a particular patient with a spectrum of conditions. EBM can be considered a complex cognitive task, requiring an instructional approach

designed for complex learning. Educational scientists have suggested the use of whole-task approaches for designing complex education[16,17] as one solution to the transfer problem. Whole-task approaches introduce learners to the combined constituent steps of an activity upfront and ask them to practice all of the requisite skills as a cohesive activity with graded levels of task complexity and support dependent on learner performance.[17-19] One such whole-task approach is the *Four Component Instructional Design* (4C/ID) model.

We propose the use of 4C/ID to guide the design of EBM training. 4C/ID is a *whole-task learning approach* based on psychological theories of learning and information processing, including Cognitive Load Theory (CLT).[20] The advantage of 4C/ID over other whole-task approaches (for a discussion of whole-task approaches see Merrill[17]) is that it supports whole-task learning with supportive mental models to enhance transfer for non-recurrent tasks and includes procedural knowledge and repetitive part-task practice to facilitate recurrent task learning. In this sense, 4C/ID is a hybrid or blended model of both whole and part-task instructional design. Also unlike other educational approaches, part-task practice in 4C/ID is only recommended to learners who have already been acquainted with the full task.

In this Perspective, we aim to describe 4C/ID and the benefits of its four components to guide the design of EBM training and improve the transfer of EBM skills learned in the classroom into clinical practice. We include illustrative examples of each 4C/ID component to demonstrate the feasibility of this approach. The examples are derived from a recent study[10] and experiences teaching EBM.

Four Component Instructional Design

4C/ID has been successfully applied in primary and higher education[16] and recently adopted in medical education to teach the complex skill of communication[21] and suggested for adoption more broadly.[22] 4C/ID includes four components: *whole-task learning*, *supportive information*, *procedural information* and *part-task training.*[20] Together these four components guide the creation of training that is designed to avoid overloading the learner's cognitive abilities, to integrate the knowledge, skills and attitudes needed to execute a complex task, and to increase transfer of knowledge to new situations.[13,20]

Whole-Task Learning

In the 4C/ID model, learning tasks are primarily presented as whole-task activities in which learners practice all constituent parts of a complex task in an integrated fashion. For example, students may be challenged to write a clinical question based on a patient's condition, locate a relevant article, critically appraise the found article and present their findings to their clinical team in a brief presentation. This use of whole-task learning enables the transfer of skills by providing learners a holistic model of how

to practice EBM[20] such that they can use it to approach clinical uncertainty in future situations.

A curriculum guided by 4C/ID includes multiple whole-tasks based on authentic examples that are sequenced from simple to complex with varying levels of support depending on the difficulty of the task and the level of the learner. Providing learners multiple and varied opportunities to practice authentic whole-tasks gives a realistic understanding of the variability of practice.[23] Variety in whole-tasks and their authenticity can be achieved by drawing on real-life clinical experiences.[21] For example, students may be required to complete whole-task EBM exercises in each of their core clerkship rotations, i.e. to ask a clinical question and propose a therapeutic approach based on recent literature. This repetition and use of a variety of learning tasks promotes transfer of the complex skill to the varied context of real life practice.[15,20]

Working memory has a limited capacity to process information and competition arises when many information elements are presented simultaneously, such as in a whole task activity[24] that utilizes authentic examples from practice, which are often inherently difficult. Therefore the use of whole-task learning poses the risk of overloading learners' cognitive capacity. [25,26] This risk can be reduced by sequencing learning tasks from simple to complex and providing task-specific information.[20,27] To sequence learning tasks appropriately, educators must consider a learner's level related to the degree of difficulty of the whole task content (e.g. the complexity of a patient case) and the format of the whole task. For example, first-year medical students can practice EBM based on narrowly defined paper cases with clinical content that has previously been covered in the curriculum whereas clerkship students might be challenged by a more multi-faceted patient presenting with a less familiar diagnosis. Educators should select learning task formats most appropriate for a learner's level. So, instead of asking novice learners to undertake authentic whole-learning tasks which provide no support and are cognitively taxing,[28] the learner may be presented a partially completed solution to work from (e.g. a completion task). This scaffolded approach should lower the learner's cognitive burden. As learners progress, the task content and format are modified by increasing the complexity and scaling back the support built into the task format[14] until the level of the task mirrors the reality of its execution in practice. The presentation of task-specific information also helps learners cope with practicing whole-tasks.[19] For example, if learners are asked to critically appraise a systematic review as the component of a whole-task learning activity they will benefit from specific information about critical review criteria and the characteristics of this publication type to successfully complete the learning activity.

Although modification of whole-task learning through sequencing and selection of task format and content reduces learners' cognitive load, it may not lower it enough to ensure that learners will be able to undertake whole-tasks.[25] Therefore, 4C/ID

recommends supportive information, procedural information and part-task practice. The inclusion of these three components further reduces cognitive load and facilitates learners' efforts to master whole-tasks, which will enable the transfer of skills from one situation to another[18].

Supportive Information

Supportive information is generally presented before learners undertake a learning task to help bridge what they already know about the task and what they need to know to complete it[20]. Supportive information helps learners tackle non-recurrent aspects of a learning task, such as components that require reasoning or problem solving[13,14]. By studying supportive information prior to undertaking a whole-task, learners create flexible cognitive schemas of how to approach the non-recurrent aspects of the whole-task[25]. Thus when performing the task, learners are able to retrieve these related cognitive schemas, which is less cognitively taxing than being presented the information during task performance, therefore, reducing the learner's overall cognitive load.

Supportive information generally takes two forms. The first form provides systematic approaches to a problem and is sometimes labeled "the theory" or background information that provides general cognitive strategies to systematically approach a problem[20]. In EBM, supportive information might be an online module that describes how an information database is structured or that provides examples of how to critically appraise meta-analyses. Examples of supportive information, such as modules focused on critical appraisal[29] and question formulation,[30] are available in MedEdPORTAL[31]. Unlike the fragmented presentation of EBM skills, supportive information is provided just prior to whole-task activities and directly applied in the practice of the whole-task. Institutions can provide learners with supportive information in several formats, such as online guides, assigned textbook chapters, and pre-recorded or in-person lectures.

The second type of supportive information provides descriptive mental models of how an individual might approach non-recurrent aspects of a problem in practice.[22] In this instance, supportive information might include a think-aloud presentation by a physician modeling her approach to searching for evidence based on a particular patient's clinical questions. She would provide descriptions of her rationale for why she has taken particular actions. This presentation would offer learners one approach, but would not serve as the only approach or an algorithmic approach due to the non-recurrent or variant nature of searching for evidence. Therefore, learners in their own settings would need to adapt this approach to fit their practice and particular patient (i.e. not simply mimic the approach presented). The ability to generalize from a presented approach or mental model is critical for the construction of new knowledge and for adapting existing schemas to a wide variety of new experiences.[28] To facilitate

this process, learners should be provided supportive information multiple times and reminded of the variability of practice, which necessitates adapting approaches to the situation at hand.

Procedural Information

Procedural information enables learners to engage in the recurrent or routine elements of a complex task by using a step-by-step or rules-based approach.[20] For example, learners might be provided a worksheet during whole task practice with a step-by-step approach to creating a clinical question using the mnemonic PICO (patient, intervention, comparison and outcome). Or, learners can be provided with step-by-step guides for critical appraisal of articles, such as the *User's Guide to the Medical Literature*.[32] With practice, this procedural information enables learners to routinize or automate their approach to this recurrent task therefore reducing cognitive load.

Procedural knowledge, also known as "just-in-time" information because it should be only delivered to the learner when they need the information, is generally provided the first time a task is introduced and within the context of the overall whole-task.[20,22] As learners have multiple opportunities to practice the skill and automate their approach, procedural information should be reduced as learners gain proficiency.[13] For example, in an EBM session second-year students may be given a detailed worksheet that guides them step-by-step though the critical appraisal of a randomized controlled trial (RCT); however, by clerkship, after several opportunities to appraise RCTs, procedural information should be unnecessary. Procedural information can take several formats, such as a manual, quick reference guide, instruction embedded in assignments or online help. For example, this could be an online guide that provides step-by-step guidance for searching information resources (i.e. how to combine Boolean operators, apply limits, etc.) to complete a required EBM assignment.

Educators can also provide procedural information by acting as "over-the-shoulder" coaches[20] providing in the moment procedural information that guides learners as they engage in recurrent components of learning tasks. Institutions provide just-in-time education via both in-person and technological means. For example, an online platform could enable students to post questions and receive answers from instructors while completing their EBM assignments. Or, librarians could circulate in a computer lab providing learners with just-in-time assistance as they craft literature searches.

Part-task practice

The fourth component of 4C/ID is part-task practice. Part-task training is introduced only after the particular task has been practiced in the context of the whole task so that learners can situate the part-task component within the larger whole task.[33] In some cases, part-task practice may be omitted if sufficient practice of all recurrent and non-recurrent skills is achieved through the general practice of whole-task learning

activities. Part-task practice is the repeated practice of a recurrent component skill that learners must automate to undertake higher-level tasks and perform the whole task under the time demands of real-world settings.[20] For example, when practicing EBM, physicians dedicate on average two minutes to literature searching.[34] Therefore, part-task practice of creating search strings in PubMed with an emphasis on quickly and correctly selecting Boolean operators (And/Or) may facilitate the realistic and rapid completion of a search enabling a learner to persist in locating evidence and practicing EBM in a short period of time.

We propose the use of 4C/ID to guide medical educators' efforts to design EBM training programs. To facilitate the use of 4C/ID, we provide an example of EBM training activities modeled on 4C/ID at both the pre-clerkship and clerkship level in Table 1. EBM training based on 4C/ID would require medical educators to consider several important factors, including: curricular time, the level of learning tasks, the potential role of technology and faculty development. Specific to EBM, we examine these issues below. General guidelines for implementing whole-task and part-task learning approaches in medical education, including 4C/ID are published elsewhere.[35]

Table 1: Examples of EBM training activities modeled on 4C/ID

Note: Ideally learners would engage in multiple EBM learning activities organized from simple to complex depending on their level throughout medical school.

	Pre-clerkship level	Clerkship level
Whole-task Activity	Based on a patient case, learners are asked to perform the steps of EBM (ask, acquire, appraise, apply) in order to propose the best next step for further investigation or treatment of a patient case.	
	For Whole-Task Content, learners: • Are provided with a written patient case derived from authentic practice, but that focuses on a single, familiar condition. For Whole-Task Format, learners: • Are provided with a set of clinical questions and asked to complete the remaining EBM steps.	For Whole-Task Content, learners: • Identify a patient case from their own clinical experience or adopt a patient case identified by a preceptor in morning rounds. For Whole-Task Format, learners: • Are tasked to identify a clinical question and execute all steps of EBM.
Supportive Information	Prior to the activity, learners: • Read an article on critically appraising diagnostic articles. • Listen to a librarian describe her thought process for selecting a database to find diagnostic articles.	Prior to the activity, learners: • Watch a short video of a physician thinking aloud through their EBM reasoning process.
Procedural Information	During the activity, learners are: • Provided a step-by-step handout to guide question formulation. • Offered over-the-shoulder feedback from roving teachers while working on a search or appraisal task.	During the activity, learners are: • Offered an online checklist to guide critical appraisal of articles.
Part-task Practice	During the activity, learners are: • Provided data on four screening modalities and challenged to calculate the likelihood ratio for each test.	During the activity, learners: • Do not engage in part-task practice if they have achieved mastery of the recurrent elements of EBM.

Practical Considerations

Training guided by 4C/ID is generally undertaken over many sessions so that learners have repeated opportunities to undertake learning activities and ensure mastery. This suggests a need to add additional learning activities to already packed curricula, which is problematic. EBM learning activities might be integrated into other curricular sessions, such as quality improvement or with educational approaches, such as problem-based learning and into clerkship rotations. This would not add additional sessions and would provide whole task practice of EBM concepts, plus the related content. Educators might also consider online learning activities, to decompress the need for face-to-face sessions.

The important role of learner level in the sequencing of learning activities raises the concern of how to provide customized learning activities for students so that they are undertaking learning tasks at their appropriate level.[20] In North America, this may especially be of concern in light of the heterogeneity of medical school classes, which may include students with backgrounds that are more aligned with EBM, such as biostatistics, and those that are less aligned like history or sociology. Adaptive e-learning may be a possibility, which would provide learners learning activities that intelligently adapt to learners' needs based on their performance of previous EBM tasks.[20,36] For example, a medical school might present its learners with an online EBM program that challenges them to undertake the steps of EBM based on a series of cases. As an adaptive system, the complexity of the patient cases and the amount of procedural information would adjust to match the specific learner's level as they progressed through the cases.

Using an approach guided by 4C/ID would challenge faculty to depart from the more traditional compartmentalized approaches of teaching EBM. For example, faculty members would be tasked with designing whole-task activities and related supportive materials. Additionally, clinical instructors should recognize that they themselves provide procedural information as models when they verbally describe to their learners the processes they undertake while practicing EBM. Teachers would also be required to take on the role of a coach, helping the learners to select learning appropriate for their level and to provide formative feedback. Dependent on learner levels, educators would need to be able to determine the correct amount of support to provide a learner and when to fade it.[19] These new types of curricular planning and pedagogical skills would require faculty development.

Conclusion

We have explored the use of 4C/ID to design curricula for teaching the complex task of EBM. Using this model, we have examined how the four components of the design might be applied to EBM along with the potential benefits that would accrue. As noted, 4C/ID takes a unique approach to learning by providing whole-task challenges, which facilitate transfer, and supporting learners in these tasks by providing supportive mental models for non-recurrent tasks and procedural knowledge and repetitive part-task practice to facilitate performance of recurrent tasks. Thus, we propose that medical educators tasked with designing EBM curriculum consider adopting the 4C/ID model.

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CHAPTER 7

Discussion

We began this thesis by introducing the importance of EBM and providing background information, including a definition of EBM, its historical context and the recommended steps for practicing EBM. In the introductory chapter, we also addressed EBM in the context of clinical care and considered challenges to its practice, including sparse information on EBM training. We concluded this chapter with the three focal research questions of this dissertation: *How is EBM practiced? How is EBM taught in medical schools? What educational models can guide the design of EBM curricula and related pedagogical strategies?* Organized around these three questions, in this chapter we briefly reiterate the main findings of our studies and consider how they contribute to answering the research questions and advance the state of EBM knowledge and medical education. We also discuss practical implications of our work, its strengths and limitations and potential future directions.

Main Findings

How is EBM practiced?

To begin, we investigated how clinicians practice EBM. Social Learning Theory posits that a student can learn values, attitudes and patterns of behavior in social environments through direct experience or through vicarious observation of others as mediated by the rewarding or punishing consequences of what they have observed.[1] Therefore, knowledge of EBM in practice provides insight into the physician behaviors that will potentially be observed by medical students, which can powerfully influence their learning and identities as physicians.[2,3] To focus our efforts, we specifically studied physicians' information needs (Chapter 2) and health personnel's access of information (Chapter 3) at the point of care. By focusing on clinical inquiry and the acquisition of information, we addressed a gap in the literature on EBM education and in the biomedical literature.[4,5] This gap is an important one to address given that clinical inquiry and acquisition of information are the initiation steps of EBM and identified as difficult aspects of EBM for physicians. [6,7]

In Chapter 2, we identified six information needs that physicians encounter in practice that can be satisfied by searching the biomedical literature. The information needs included: refreshing, confirming, logistical information, teaching, information generating and personal learning. Although the findings of this study somewhat align with earlier efforts to create clinical question taxonomies,[8,9] they extend prior work by adding two additional information needs, teaching and idea generating. The identification of these information needs can potentially be used to structure an educational approach to support physicians in the variety of roles they undertake in practice, such as teacher and lifelong learner. This study also provides further insight into how physicians satisfy these information needs through the use of the information resources PubMed, a biomedical literature database and UpToDate, an evidence summary tool both of which are heavily used in clinical practice.[10,11] Through

our interviews, we identified that physicians use different information resources for similar information needs. For example, we observed that for refreshing and confirming knowledge both Pubmed and UpToDate were used. This finding may suggest that physicians' information needs are nuanced and context specific, thus different information resources are appropriate depending on the situation.

Building on the findings of Chapter 2, we further examined the information use of health professionals to better understand the information resources that are accessed in practice (Chapter 3). As much of what is known about information use behavior by health personnel is self-reported and not limited to the context of clinical care,[12-14] we analyzed Stanford University Hospital's web logs over the course of a year to determine the information access patterns of health personnel when caring for patients. In undertaking this study, we developed a web log methodology that automates the mass retrieval of article-level metadata of articles accessed via PubMed and UpToDate. This methodology extends researchers' ability to extract details of the articles being accessed such as the topics of articles, publication types (e.g. review article, meta-analysis, and/or clinical trial) and publication dates. Prior research reports physician information use by only identifying the information resources used such as UpToDate and Google Scholar.[11,15] Researchers can now utilize this methodology and the resulting details to more deeply understand clinicians' information use and tailor training accordingly. For example, our new methodology has been adopted by an ongoing randomized controlled study of physician information use funded by the US National Science Foundation.[16]

In Chapter 3, we determined that at Stanford University Hospitals in the US health personnel, including physicians, nurses and hospital administrators, visited UpToDate, which presents topical overviews of the available literature, more than twice as often as PubMed (110, 336 versus 47,244 visits over year), which connects users with individual articles. This finding reinforces earlier self-reported data on the heavy use of UpToDate in clinical practice.[10,11] However, our study extends prior research by describing the limited use of UpToDate's hyperlinked bibliographies, which connect users to articles. Use of these article links accounted for only 3% (2,474 clicks) of the 81,851 total articles viewed suggesting that health personnel use UpToDate primarily for its topical reviews in practice despite this additional functionality as a connector to primary literature. Similarly, of the articles accessed via PubMed and UpToDate, review articles (n=24,529) were the most common publication type accessed accounting for 30% of all accessed articles. These combined findings suggest that health personnel heavily utilize review resources when practicing EBM. This heavy use of review materials indicates a potential disconnect from the traditional 5A's approach to EBM,[17] which generally features the critical appraisal of studies and suggests that training might be modified to include how to appraise review articles as well as information resources used by physicians that present topical overviews, such

as UpToDate and Wikipedia.[18] Despite this use of review articles, it continues to be important for learners to know how to locate and appraise individual studies, as review articles are not available for all topics. Therefore, these findings suggest the need to expand EBM training to include instruction related to reviews, topical overviews and individual studies.

To answer our question of *how EBM is practiced*, we conducted two studies focused on clinical inquiry and the acquisition of information. Our findings advance the knowledge of how EBM is practiced by identifying additional physician information needs and by highlighting that information access in practice, which is highly reliant on review services and articles, does not synchronize with current training practices. Medical educators can utilize these finding to inform EBM training and better align it with the realities of clinical practice.

How is EBM taught in medical schools?

For over 20 years, EBM has been included in medical school curriculum.[19] Yet, there is limited information on *how* EBM is taught at this level which has implications for medical education.[20] Therefore, to answer the question of how EBM is taught in medical schools, we conducted the two studies reported in Chapters 4 and 5 to better understand how institutions offer EBM training and the challenges that medical students face when learning EBM. Drawing on Social Learning Theory[1] we also explore findings from our studies in Chapters 2 and 3, both of which were undertaken at academic medical centers, to consider how physicians' displays of information needs and information use and the resulting consequences of such displays, which are observed by medical students, might contribute to how EBM is taught.

To characterize how EBM is formally taught in medical schools we began by conducting a review and critique of the recent literature in Chapter 4. This review identified 20 educational interventions designed to teach medical students EBM and provided details of the training, such as educational settings, EBM skills presented, teaching methods used and learner characteristics. Our study concluded that while all of these EBM interventions taught some combination of EBM skills, none addressed all six EBM skills.[21] Most training included how to ask a clinical question, acquire relevant evidence, appraise found evidence and apply it to patient care. Four interventions included training related to the acknowledgement of knowledge gaps and only a single intervention addressed assessment of practice. This uneven coverage of EBM skills highlights a need for more comprehensive EBM training to ensure that all skills are addressed. We also concluded that the reviewed interventions lacked robust outcome measures and suggested more detailed reporting of EBM interventions to allow for evaluation and if warranted replication of interventions. This synchronizes with a recent BEME systematic review that similarly concluded that there is insufficient evidence that EBM teaching improves learners' behaviors or results

in long-term mastery of EBM.[22] Drawing on our findings, researchers have built upon our work to create guidelines for how publications should report details of educational EBM interventions.[23,24]

In light of the limited information on EBM training for medical students, in Chapter 5, we interviewed faculty at a sample of medical schools that graduated students confident in their abilities to practice EBM according to data from the Association of American Medical Colleges Graduation questionnaire. We asked study participants, employed at these schools to describe the strengths of their curriculum, what they felt were challenges to students learning EBM and the ways in which their formal curriculum attempted to meet these challenges. We identified four student learning challenges including suboptimal role models, unwillingness to admit uncertainty, lack of clinical context and difficulty mastering EBM skills. These challenges add to prior research findings that describe physician barriers to practicing EBM[25-27] and resident challenges[28,29] by adding the student perspective. The addition of this new perspective may provide medical educators with additional insights into how students experience EBM training and can help guide EBM curricular design. Additionally, our findings provide learner-centric information that compliments faculty-centered research identifying barriers to teaching EBM.[20,30,31] Knowledge of student challenges, as described by the EBM faculty, provides a glimpse into the "experienced curriculum"[32] of EBM i.e. what the students might experience when they learn EBM, which provides medical educators additional insights for guiding future EBM curricular design. In Chapter 5, we also identified five approaches to overcoming student learning challenges, which medical educators can also use as potential strategies for designing EBM training. Several of these approaches align with learning theories, including Social Cognitive Theory,[33] Cognitive Apprenticeship,[34] Workplace Learning Theory,[35] Social Learning Theory[1] and Situated Learning Theory .[36]

Of note, institutions commonly offered faculty development, typically with a focus on bolstering faculty's EBM skills.[20,37] Our findings suggest extending this traditional faculty development approach by highlighting the need to train faculty to be cognizant of their status as EBM role models and to be explicit in their practice of EBM. This finding aligns with Social Learning Theory[1], Social Cognitive Theory[33] and Cognitive Apprenticeship[34] and corresponds with research that has concluded that effective physician role models need to be consciously aware of role modeling and be clear about their processes when working with learners.[3] Also efforts to integrate EBM training longitudinally across the curriculum, including into clinical clerkship experiences, aligns with Situated Learning Theory[36] and Workplace Learning Theory[35], which highlight the importance of learning taking place within the context of where the work will authentically take place to promote learning.

As medical students learn from observing physician role models in practice[3] the findings from our studies presented in Chapters 2 and 3 also contribute to understanding how EBM is taught to medical students. These studies provide insight into the informal EBM curriculum, which is the "unscripted, predominantly ad hoc, and highly interpersonal form of teaching and learning that takes place among and between faculty and students".[38] Therefore, this knowledge is helpful in ensuring that the informal curriculum synchronizes with what is taught or at least does not "extinguish" what is taught in formal EBM training as was feared by faculty in our study reported in Chapter 5. Additionally, these studies of EBM in practice provide insight into how two of the sub-skills of EBM (ask and acquire), which we identified as less covered in our review of the EBM literature (Chapter 4), and help fill a gap in our understanding of how these two EBM skills are taught.

In these studies, we identify and describe how EBM is taught both formally and informally in medical school curricula. Through our study of published EBM trainings, we provide characteristics of the trainings such as learning modalities used and student populations taught, however, we conclude that there is a need for increased details when reporting EBM educational interventions. To help fill this gap, we describe challenges that students face when learning EBM and approaches that institutions take to address them in their curriculum. We also describe how physicians' information needs and information use in practice contribute to how EBM is taught to medical students.

What educational models can guide the design of EBM curricula and related pedagogical strategies?

The reported lack of EBM skills in practice[25,26,39] may indicate a weakness in the manner in which EBM instruction is designed. Currently there is no generally endorsed educational model for teaching EBM in medical schools.[40] However, researchers have identified that the structure or lack thereof of EBM training may impede learners' ability to transfer EBM knowledge and skills into future clinical practice.[20] Therefore, in Chapters 4 and 6, we considered pedagogical strategies for EBM teaching and a potential model for designing EBM curricula to optimize the transfer of skills.

In Chapter 4, we suggest several pedagogical approaches to teaching EBM. These approaches are based on the trends we identified in our review of EBM educational interventions (Chapter 4), educational theory and our experience as EBM practitioners and teachers. The approaches include optimizing the timing of EBM instruction in the curriculum, designing longitudinal EBM training, incorporating interprofessional EBM instruction, using active and online learning environments and increasing the inclusion of training on the acknowledgment of knowledge gaps. While some of these approaches have been applied in EBM education at individual medical

schools, such as the implementation of a longitudinal EBM curriculum[41-43] and the use of interprofessional instructors[44,45] and align with Adult Learning Theory[46] through the use of self-directed learning approaches that are problem based they have not been widely adopted. In some cases, we identified the application of these educational approaches at the institutions that participated in our study in Chapter 5. However, one approach that was frequently used by institutions in Chapter 5, but that did not surface in our literature review, was the use of *whole-task learning exercises*.

Whole-task learning exercises challenge learners to practice all constituent parts of a complex cognitive task in an integrated manner and have been linked with increasing learners' ability to transfer skills into practice.[47,48] This approach contrasts with the more common atomistic approaches of teaching EBM[49,50] that are generally connected to fragmentation of learning and lack of skills transfer.[51,52] In Chapter 6, we explore the applicability of whole-task learning exercises for EBM training and specifically suggest the use of the whole-task *Four Component Instructional Design* (4C/ID)[53] model as a potential guide for designing EBM education in order to optimize transfer of EBM skills into practice. As the use of whole-task learning activities can heavily tax the cognitive resources of learners,[54,55] we suggest the use of 4C/ID, which aligns with Cognitive Load Theory.[56] 4C/ID takes into account learners' cognitive capacity[57] by including whole-task activities. Whole-task activities in this model are supported by supportive and procedural information and part-task training to mitigate learners' cognitive load. This is the first instance that 4C/ID has been specifically suggested for use with EBM training although in Chapter 5 institutions utilized whole-task learning activities to address learners' difficulty mastering EBM skills and lack of willingness to admit uncertainty. Additionally, 4C/ID has been recently been implemented in the creation of communication[58] and clinical reasoning training[59] for health professionals. In these instances, 4C/ID has been connected with helping to reduce learners' cognitive load and to prepare them for practice.

Strengths and limitations of this thesis

One strength of this thesis was the use of multiple methods to investigate our three main research questions that included a formal review of the EBM literature, qualitative interviews and web log analysis. Through the combination of these methods, we have contributed new insights into how EBM is practiced and taught as well as how EBM training could be designed based on educational theory and instructional design principles. However, this thesis must also be considered in light of it limitations.

To begin, we described in Chapter 1 that the barriers to practicing EBM are multi-factorial. While EBM training can help mitigate some of these barriers, educational interventions alone may be insufficient. Therefore, our educational findings and suggestions should be considered in relation to other barriers. For example, the lack

of time clinicians have at the point of care to practice EBM and teach EBM is often identified as a major barrier to EBM[25,26,29], which can impede physicians' ability to serve as role models for their learners. While improved education may help to overcome this barrier there may be a need for more systematic approaches to this time barrier such as increasing the availability of organizational resources.

In this thesis, we primarily define EBM based on Sackett's definition of EBM, which may be a narrow conceptualization. Sackett defines EBM as "the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients".[60] While this definition continues to be widely cited, recently EBM proponents and critics have suggested modifications and alternate ways of conceptualizing EBM. For example, there has been a movement to further incorporate the patient into shared decisions about their health.[61] A broadening of the definition of EBM may introduce alternate ways of understanding and teaching EBM.

While our combination of multiple methods in this thesis provided valuable findings, we did not directly observe EBM in practice or EBM being taught. Direct observation in both of these contexts would have been helpful in answering our research questions, especially in regards to how EBM is practiced; earlier studies have demonstrated that physicians are suboptimal reporters of their EBM activity.[62]

While we conducted a global review of the published literature in Chapter 4, our remaining studies focused on participants affiliated with North American and Dutch medical schools. It is possible, that the replication of our studies in other world regions, perhaps that have less ready access to technology and biomedical information or that operate using different curricular structures, would have provided additional valuable information. Additionally, our studies focused primarily on physicians and medical students. However, other health professionals, such as dentists,[63] nurses,[64] and public health administrators[65] also act as evidence-based practitioners and incorporate EBM into their educational initiatives. Knowledge of EBM practices from other health professionals may be valuable in designing EBM education and facilitating interprofessional collaboration related to the use of evidence for patient care. Similarly we only examined EBM in the context of academic medical centers. Identifying those in practice outside of academia might have provided additional insights into how physicians practice and what current students can expect to experience in the future.

Related to information use, our studies were somewhat limited in that they focused specifically on the information resources PubMed and UpToDate. Despite being heavily used in clinical care[10,11] these are not the only resources used by physicians. Additionally, the availability of information and information resources is continually expanding with resources such as Google Scholar and Wikipedia gaining popularity in medicine and increasing in quality.[10,18,66-68] Future research should take into

consideration additional information resources, including the use of information resources delivered via the electronic health record and from patients, and how they can be best incorporated into EBM training. Another strength of this thesis is that we have presented an objective method for studying physician information use, which can be leveraged by other researchers and applied to a variety of information resources.

Suggestions for the practice of medical education

The findings from our studies provide valuable information for advancing EBM training and facilitating the optimal practice of EBM in the future. We now consider how medical educators might apply these findings.

An understanding of how EBM is practiced in patient care, such as described in Chapters 2 and 3, can help medical educators teaching at all levels of medical education to calibrate their approach to EBM training so that it aligns with clinicians' practices, supports the practitioner' needs and prepares early learners for the realities of practice. In our studies, we provide information from practice specifically about physicians' clinical inquiry and information seeking that can inform EBM education. For example, our findings indicate that physicians have a variety of information needs in the course of patient care. However, current models for EBM training related to asking questions usually focus on the formulation of PICO questions.[5,7] While PICO questions are valuable for creating patient-centered questions relevant for searching the primary biomedical literature,[69] they may be less relevant to physicians seeking to refresh their knowledge of a general medical topic. Therefore, we suggest that medical educators utilize our findings on information needs and information use to inform educational initiatives so that they synchronize with the realities of medical practice and provide learners with strategies for fulfilling all of their information needs. Additionally, knowledge of how EBM is practiced provides insight for information and computer scientists that are attempting to design tools, such as information resources that are integrated with the electronic health record, and trainings to facilitate the optimal use of information.

In addition to raising awareness of how EBM is practiced, our findings on EBM training in medical schools also provide new information on how EBM is taught both formally and informally. Medical educators can use this knowledge to examine their own curriculum and learning environments and, if desired, adopt new ideas and approaches. For example, medical educators might consider whether or not the identified student learning challenges, such as lack of faculty role models and/or student unwillingness to admit uncertainty, are also found at their institution. If the challenges are present, they may then consider adapting their EBM training to mitigate them by possibly using the suggested educational approaches identified in Chapter 5, the 4C/ID model highlighted in Chapter 6 or the approaches described in the review of the literature in Chapter 4. Related to the informal EBM curriculum,

we identified the lack of suboptimal faculty role models, which has the potential to undermine the formal curriculum. This finding, which has also been noted in the literature,[20,31] suggests a need for medical educators to not only focus on formal student training, but also to be aware of how students are observing their faculty practice EBM and if necessary to offer faculty development, such as suggested in Chapter 5 to ensure positive role models for learners to follow.[1]

In this thesis, we propose the use of a formal instructional design model to help guide medical educators in creating EBM training. Although models exist for practicing EBM,[21] there currently is limited guidance on how to teach EBM. Our suggestion of the 4C/ID model provides educators with a potential plan for creating whole-task learning activities, which promote the transfer of skills into practice and for supporting learners in these whole-tasks by including supportive and procedural information and part-task practice. To facilitate the use of this model, this thesis presents medical educators with an example of EBM training activities designed using 4C/ID, which could be adopted, and practical considerations for implementing such a training approach. To facilitate the adoption of 4C/ID, faculty development would be necessary to learn about 4C/ID and to determine how to apply it in a particular setting.

Implications for future research

In this thesis, we have made steps to better understand EBM use in practice and EBM training in medical schools. However, our findings also prompt additional questions for future research.

To begin, despite our efforts to describe EBM curriculum the picture of EBM training in medical schools that we present remains incomplete. Through our studies we provide insight into formal and informal EBM curricula. However, curriculum has been described as an amalgamation of formal, informal and hidden curricula.[38] The hidden curriculum refers to a "set of influences that function at the level of organizational structure and culture".[38] Future researchers should examine the hidden EBM curriculum at medical schools to create a more holistic understanding of EBM, which could facilitate the future design of EBM curriculum.

In our studies, we defined EBM based on Sackett's traditional definition of EBM. While we believe this definition remains relevant to the practice and teaching of EBM, future research may benefit from posing research questions that consider EBM in relation to modified definitions that reflect the interprofessional nature of patient care such as put forth by the Sicily Conference[70] or emphasize the active role of the patient in the EBM process.[39] In addition to considering the evolving definition of EBM, future researchers might also consider the ways in which the practice of EBM has changed in light of technological advances and how the execution of the steps of EBM

should or should not be modified to accommodate them. For example, the utilization of the electronic health records potentially adds another layer of evidence for EBM practitioners to consider when practicing the acquire step of EBM and applying the evidence to their specific patient.[71]

In this dissertation, we consider EBM a complex cognitive skill and have focused on the relevant educational approach of designing EBM education using 4C/ID, which aligns with Cognitive Load Theory.[57,72] However, the use of additional cognitive and social theoretical approaches such as Workplace Learning Theory,[35] Situated Learning Theory,[36] Cognitive Apprenticeship[34] and Social Cognitive Theory[33] may also be valuable for examining EBM. For example, based on our findings related to the lack of optimal EBM role models, future researchers might pose questions using the lens of Social Cognitive Theory[33] or Cognitive Apprenticeship[34] to better understand EBM education and inform future trainings. This line of inquiry would explore the influence of EBM role models on learner behavior and motivation.

Conclusion

The research undertaken in this thesis aims to make a contribution to the medical education literature about how EBM is practiced by physicians and taught in medical schools. In this thesis we addressed the questions: *How is EBM practiced? How is EBM taught in medical schools? What educational models can guide the design of EBM curricula and related pedagogical strategies?* Our findings help to answer these questions and provide suggestions for medical education to modify their approaches to teaching EBM and to researchers to explore future questions.

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Summary

Evidence-based medicine (EBM) has been defined by David Sackett as the "conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients". The practice of EBM is an expectation of professional organizations for practicing physicians and a requisite component in many medical school curricula. Yet, despite training physicians sub-optimally practice EBM in clinical care due to a range of factors. Education may help to mitigate these factors and improve how EBM is practiced. Therefore, it is important to understand how EBM is practiced in clinical care and taught in order to inform how EBM education may be best designed to address these factors, which pose a challenge to preparing physicians to practice EBM. The chapters in this thesis attempt to provide this information to advance the state of EBM knowledge and medical education.

In Chapter 1, we introduce the historical context of EBM, EBM definitions, recommended steps for practicing EBM and models associated with the steps. The chapter also addresses the current state of EBM in clinical care and considers barriers to its practice, including those posed by the lack of available information on EBM training. This chapter concludes by presenting the three central research questions that this dissertation addresses:

- *How is EBM practiced?*
- *How is EBM taught in medical schools?*
- *What educational models can guide the design of EBM curricula and related pedagogical strategies?*

Chapter 2 describes a qualitative study in which we aimed to identify physicians' information needs in clinical care and how they correspond with use of the popular information resources PubMed and UpToDate. We interviewed participants using a semi-structured interview protocol in the United States (US) and the Netherlands. We interviewed 22 physicians (US n=13; Dutch n=9). Using thematic analysis, we identified six information needs: refreshing, confirming logistics, teaching, idea generating and personal learning. Participants used both PubMed and UpToDate to satisfy the identified information needs. We did not appreciate differences between the US and Dutch participants identification of information needs or their use of PubMed and UpToDate. Our results expand upon the existing literature on physician information needs and sheds light on how physicians use information resources to satisfy these needs. Findings from this study may be used to inform educational approaches for the design of EBM training for physicians.

Chapter 3 presents a yearlong weblog study conducted in 2011 to determine the types and quantity of research evidence accessed by 5,042 health personnel providing clinical care at Stanford University Hospitals. This study focused on health personnel's access of articles via PubMed, a bibliographic database and UpToDate, a resource that presents topical summaries of the available literature, but that also links to articles. For this study, we developed a web log methodology that automates the mass retrieval of article-level metadata of articles accessed via PubMed and UpToDate. This methodology extends researchers' ability to extract details of the articles being accessed such as the topics of articles, publication types (e.g. review article, meta-analysis, and/or clinical trial) and publication dates.

Our findings demonstrated that health personnel visited UpToDate more than twice as often as PubMed (110, 336 versus 47,244 visits over year). Via both PubMed and UpToDate, 81,851 total articles were viewed with only 3% (2,474 clicks) of articles accessed via UpToDate. This finding suggests that health personnel access UpToDate primarily for its topical reviews despite its links to primary literature. Similarly, of the total articles accessed review articles (n=24,529) were the most common publication type accessed accounting for 30% of all accessed articles. Findings from this study suggest that health personnel heavily utilize review resources when practicing EBM. This pronounced use of review materials may indicate a disconnect with how EBM is practice and how it is traditionally taught, which generally includes attention to the critical appraisal of studies and suggests that modifications to training might be warranted.

Chapter 4 features our review of the recent biomedical literature, published between 2006–2011, which characterizes training designed to teach medical students EBM. We identified 20 educational interventions based in 12 countries. From these studies, we extracted the details of the interventions, such as educational settings, EBM skills presented, instructor characteristics, teaching methods used and learner characteristics. Identified interventions took place in classroom (75%), clinic (25%) and/or online environments (20%) and were primarily taught by physicians (60%) who co-taught with librarians (20%) and allied health professionals (10%) and faculty from other disciplines (10%), such as business administration. The majority of interventions included the EBM skills of how to ask a clinical question, acquire relevant evidence, appraise found evidence and apply it to patient care. Four interventions included training related to the acknowledgement of knowledge gaps and only a single intervention addressed the assessment of practice. Unfortunately, due to the limited amount of details provided in the articles about the interventions and their evaluation we were unable to draw conclusions about the efficacy of the interventions. We suggested that future authors provide more detailed reporting of EBM interventions to allow for evaluation and if warranted replication of interventions.

In Chapter 5, we present a qualitative multi-institutional case study of selected EBM curricula in North American medical schools that identifies challenges to learning EBM and educational approaches to meet them. Based on Association of American Medical Colleges 2012 Graduation Questionnaire data, we interviewed 31 EBM educators (17 clinicians, 11 librarians, 2 educationalists and 1 epidemiologist) from selected institutions (13 in the United States; 4 in Canada) with graduates reporting confidence in their EBM skills. From these institutions we also requested curricular materials, such as EBM assignments and syllabi. In the interviews, we asked to participants to describe EBM learning challenges and describe their EBM curriculum. We identified sub-optimal role models, student lack of willingness to admit uncertainty, lack of clinical context and difficulty mastering EBM skills as EBM learning challenges. Identified educational approaches to these challenges included integration of EBM skills with other content/courses, incorporation of clinical content, faculty development, use of whole-task activities and longitudinal integration of EBM. Our identification of these four learner-centered challenges expands upon the available literature on barriers to learning EBM. The five educational approaches provide potential strategies for medical educators to inform their EBM training.

In Chapter 6, we propose that medical educators consider using the *Four Component Instructional Design* (4C/ID) model to guide the design EBM training. Based on current cognitive psychology, including Cognitive Load Theory, 4C/ID posits that complex skills training, such as EBM training, should include four components: whole-task learning activities, supportive information, procedural information and part-task practice. The combination of these four components can be used to inform the creation of complex skills training that is designed to avoid overloading learners' cognitive abilities, to facilitate the integration of the knowledge, skills and attitudes needed to execute a complex task and to increase transfer of knowledge to new situations. This chapter introduces 4C/ID and describes the benefits of its components to facilitate the design of EBM training. We include within these descriptions examples of educational practices that are consistent with 4C/ID and that can be applied to teaching EBM. We conclude by suggesting that medical educators consider adopting 4C/ID to design, modify and/or implement EBM curricula in classroom and clinical settings.

Chapter 7 aims to summarize the main findings of the thesis. In this chapter, we consider the ways in which these findings help answer the main research questions of the thesis and advance what is known about how EBM is practiced and taught. We also describe the strengths of the thesis such as our use of multiple methodologies and weaknesses, including the somewhat narrow, yet traditional, way in which we define EBM. In this chapter, we also make suggestions for the practice of medical education, such as the suggestion to utilize our findings related to EBM in practice to synchronize educational initiatives with the realities of current medical practice. Lastly, we also

suggest directions for future research. Suggestions included an exploration of the hidden EBM curriculum, and consideration of advances in information technology, including the ways in which they may impact the practice and teaching of EBM.

Overall the research undertaken in this thesis aims to make a contribution to the medical education literature about how EBM is practiced by physicians and taught in medical schools. In this thesis, through s series of studies, we addressed the questions: *How is EBM practiced? How is EBM taught in medical schools? What educational models can guide the design of EBM curricula and related pedagogical strategies?* Our findings help to answer these questions and provide suggestions for medical education to modify their approaches to teaching EBM and to researchers to explore future lines of inquiry.

Samenvatting

Evidence-based medicine (EBM) is door David Sackett gedefinieerd als de "het gewetensvol, expliciet en oordeelkundig gebruik van het huidige beste bewijsmateriaal om beslissingen te nemen over de zorg voor individuele patiënten". Professionele organisaties verwachten van praktiserend artsen dat zij EBM toepassen en achten EBM een noodzakelijke component in medische curricula.

Hoewel medische opleidingen aandacht besteden aan EBM wordt het in de klinische zorg sub-optimaal toegepast; dat is te wijten aan meerdere factoren. Onderwijs kan helpen deze factoren te beperken en de manier waarop EBM wordt beoefend te verbeteren. Het is van belang te begrijpen hoe EBM thans wordt toegepast in de klinische zorg en hoe het wordt onderwezen, om te bepalen hoe het EBM onderwijs het best verder kan worden ontwikkeld en hoe de beperkingen bij de voorbereiding van artsen op gebruik van EBM in de praktijk uit te oefenen kunnen worden weggenomen. De hoofdstukken in dit proefschrift trachten met deze informatie de stand van zaken met betrekking tot de kennis van EBM en medisch onderwijs op een hoger plan te trekken.

In hoofdstuk 1 introduceren we de historische context van EBM, de definities, de aanbevolen stappen voor het uitoefenen van EBM en de daarmee gepaard gaande modellen. Het hoofdstuk behandelt ook de huidige stand van zaken met betrekking tot EBM in de klinische zorg en bespreekt belemmeringen die voorkomen in de praktijk, mede als gevolg het gebrek aan kennis over optimale EBM training. Dit hoofdstuk sluit af met de presentatie van de drie centrale onderzoeksvragen die in dit proefschrift behandelt:

- *Hoe wordt EBM beoefend?*
- *Hoe wordt EBM onderwezen in medische opleidingen?*
- *Welke onderwijskundige modellen kunnen richting geven aan het ontwerp van EBM curricula en onderwijsmethoden?*

Hoofdstuk 2 beschrijft een kwalitatieve studie waarin we tot doel gesteld hebben om de informatiebehoefte van artsen in de klinische zorg te identificeren en hoe deze overeenstemt met het gebruik van de populaire informatiebronnen PubMed en UpToDate. We interviewden deelnemers met behulp van een semi-gestructureerd interview protocol in de Verenigde Staten (VS) en in Nederland. Wij interviewden 22 artsen (US n = 13; Nederland n = 9). Met behulp van thematische analyse, ontdekten we zes informatiebehoeften: opfrissen van kennis, checken van eigen of andermans veronderstellingen, onderwijs geven, genereren van nieuwe ideeën en bevredigen van persoonlijke leerbehoefte. De deelnemers gebruikten PubMed en UpToDate om informatie te verkrijgen over hun informatiebehoefte. We vonden geen verschillen tussen de Amerikaanse en Nederlandse deelnemers in informatiebehoefte of gebruik

van PubMed en UpToDate. Onze resultaten vullen de bestaande literatuur over de informatiebehoefte van artsen aan en verhelderen hoe artsen gebruik maken van informatiebronnen om aan deze behoefte te voldoen. De resultaten van deze studie kunnen worden gebruikt bij de ontwikkeling van EBM onderwijs voor artsen te informeren.

In hoofdstuk 3 wordt een een studie op basis van weblog-data van een jaar gepresenteerd, uitgevoerd in 2011, om de typen en hoeveelheid evidence-bronnen vast te stellen die benaderd zijn door 5042 medische zorgverleners werkzaam bij de Stanford University Hospitals. Wij onderzochten het benaderen door gezondheidspersoneel van artikelen via PubMed, een bibliografische database, en via UpToDate, een bron die actuele samenvattingen van de beschikbare literatuur bevat en waarbij tevens naar de artikelen kan worden doorgelinkt. Voor dit onderzoek hebben we een web-log methodiek ontwikkeld die de grote hoeveelheden papers die dagelijks via PubMed en UpToDate worden benaderd als metadata kan automatiseren op artikelniveau. Deze methode helpt onderzoekers details te extraheren van de artikelen die worden gezocht zoals het onderwerp, type publicatie (zoals recensies, meta-analyses, of klinische trials) en verschijningsdatum.

Wij vonden dat zorgverleners UpToDate meer dan twee keer zoveel raadpleegden als PubMed (110, 336 versus 47.244 bezoeken op jaar basis). Via PubMed en UpToDate werden in totaal 81.851 artikelen bekeken waarvan slechts 3% (2474 clicks) via UpToDate. Dit betekent dat UpToDate vooral voor actuele reviews wordt gebruikt, ondanks alle links naar primaire literatuur die het bevat. Ook vormden reviewartikelen (n = 24.529) de meest gezochte van alle publicatie typen, nl 30%. Bevindingen van deze studie suggereren dat zorgverleners zwaar leunen op reviews bij het beoefenen van EBM. Het overwegende gebruik van reviews contrasteert met het gangbare onderwijs in EBM dat gericht is op critical appraisal van originele studies, en leidt wellicht tot heroverwegen van het onderwijs.

Hoofdstuk 4 bevat een overzicht van de biomedische literatuur tussen 2006 en 2001 over de training van geneeskundestudenten in EMB. Wij identificeerden 20 onderwijsinterventies in 12 landen. Uit deze studies verzamelden wij details zoals de onderwijssetting, de EBM-vaardigheden die centraal stonden, kenmerken van de betrokken docenten, onderwijsmethoden en kenmerken van de studenten

Het onderwijs vond plaats in onderwijsruimten (75%), in de kliniek (25%) en/of online (20%) en werd vooral verzorgd door artsen (60%), vaak samen met bibliotheekpersoneel (20%), andere zorgverleners (10%) en personeel van andere faculteiten zoals bestuurswetenschappen. De meerderheid van de de onderwijsinterventies betrof het stellen van klinische vragen, het vinden van relevante evidentie, beoordelen van evidentie en toepassen in de patiëntenzorg. Vier

interventies betroffen een training in herkennen van kennislacunes en slecht een betrof een toetsing aan de praktijk. Helaas zijn slechts weinig details gepubliceerd over uitvoeringen en toepassingen, waardoor het niet mogelijk is conclusies te trekken over de effectiviteit van de interventies. Wij bevelen aan dat auteurs meer details publiceren zodat de EBM interventies beter geëvalueerd en zonodig gerepliceerd kunnen worden.

In hoofdstuk 5 presenteren we een kwalitatieve casestudie bij meerdere Noord-Amerikaanse medische opleidingen over barrières in het onderwijs van EBM en hoe deze in het onderwijs zijn benaderd. Op grond van een in 2012 door de Association of American Medical Colleges afgenomen afstudeervragenlijst interviewden we 31 EBM docenten (17 clinici, 11 bibliothecarissen, 2 onderwijskundigen en 1 epidemioloog) van geselecteerde onderwijsinstellingen met afgestudeerden die veel vertrouwen rapporteerden in hun EBM vaardigheden (13 in de VS en 4 in Canada). Ook vroegen wij onderwijsmateriaal op, zoals opdrachten en syllabi. In de interviews vroegen wij naar de belangrijkste problemen met het aanleren van EBM vaardigheden en naar een beschrijving van het EBM onderwijs. De problemen betroffen een gebrek aan goede rolmodellen, een weerstand bij studenten om onzekerheid te erkennen, een gebrek aan klinische context en moeilijkheden bij een aanleren van EBM vaardigheden. De onderwijsaanpak voor deze problemen omvatten de integratie van EBM vaardigheden met ander onderwijs, het gebruik van klinische stof, docententrainingen, het toepassen *whole-task* activiteiten en longitudinale integratie van EMB. De vier beschreven problemen zijn een toevoegingen aan de bestaande literatuur. De vijf onderwijsbenaderingen vormen strategieën die bruikbaar zijn voor medische docenten.

In hoofdstuk 6 geven wij docenten in overweging het *Four Component Instructional Design* (4C/ID) model toe te passen bij EBM training. 4C/ID is gebaseerd hedendaagse cognitief-psychologische inzichten, inclusief de *Cognitive Load Theory,* en stelt dat complexe vaardigheden, zoals EBM training, vier componenten bevatten: *whole-task* leeractiviteiten, ondersteunende informatie, procedurele informatie en deel-taak oefening. De combinatie van deze vier componenten kan bijdragen aan training voor complexe vaardigheden op een manier die cognitieve overbelasting kan verminderen, integratie kan bevorderen van de kennis, vaardigheden en attitude die nodig zijn bij complexe taken en transfer van kennis naar nieuwe situaties mogelijk kan maken. Dit hoofdstuk introduceert 4C/ID en beschrijft de toepassingen bij EBM trainingen. Wij hebben voorbeelden toegevoegd van onderwijsmethoden die bij 4C/ID passen en bruikbaar zijn in EBM onderwijs. Als conclusie bevelen wij EBM docenten aan 4C/ID te overwegen en hun EBM onderwijs hiermee aan te passen of volledig ermee in te richten, in het preklinische en het klinisch onderwijs.
Hoofdstuk 7 vat de belangrijkste bevindingen van het proefschrift samen. In dit hoofdstuk bespreken we hoe de bevindingen de hoofdvragen van het proefschrift beantwoorden en hoe onze kennis over hoe EBM wordt toegepast en onderwezen hiermee toeneemt. Wij geven ook de sterktes van het proefschrift aan zoals de

toepassing van uiteenlopende onderzoeksmethoden en de zwaktes, zoals de enigszins nauwe, zij het traditionele, definitie van EBM. In dit hoofdstuk worden ook praktische aanwijzingen voor onderwijs gegeven, zoals de aanbeveling om onze bevindingen te gebruiken bij het stroomlijnen van EBM onderwijs met de hedendaagse klinische praktijk. Ten slotte geven we voorstellen voor toekomstig onderzoeksrichtingen, zoals naar verborgen EBM-curriculumaspecten en ontwikkelingen in de informatietechnologie, waaronder die welke de praktijk en het onderwijs in EBM kunnen beïnvloeden.

Samenvattend beoogt het onderzoek van dit profschrift bij te dragen aan de medisch-onderwijskundige literatuur over de toepassing van EBM door artsen en in het medisch onderwijs. De vragen die wij ons stelden, in een serie van onderzoeken in dit proefschrift, waren: *Hoe wordt EBM beoefend? Hoe wordt EBM onderwezen in medische opleidingen? Welke onderwijskundige modellen kunnen richting geven aan het ontwerp van EBM curricula en onderwijsmethoden?* Onze bevindingen helpen bij de beantwoording van deze vragen, geven suggesties aan medische opleidingen om hun benaderingen van EBM onderwijs aan te passen en spoort onderzoekers aan toekomstige onderzoeklijnen op dit gebied uit te zetten.

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Curriculum Vitae

Lauren Maggio was born on November 8, 1979 in Massachusetts in the United States (US). In 2001, she completed her bachelor's degree at Tufts University in the US where she studied English literature. After graduation, Lauren served as an AmeriCorps VISTA.

Subsequently, Lauren attended the University of British Columbia in Canada to study children's literature. She received her master's in children's literature in 2003. Next, Lauren studied library and information science at Simmons Graduate School of Library and Information Science in Boston in the US. Her master's degree in library and information science was granted in 2005. In 2011, Lauren began her PhD in the University of California, San Francisco and University of Utrecht collaborative doctoral program in health professions education.

Upon receiving her degree in library science in 2005, Lauren worked at the Boston University Medical Center Library as the Head of Education and Information Management until 2008. In 2008, Lauren began working at Stanford University's Lane Medical Library as an information services librarian and in 2011 she became the Director of Research and Instruction. At Stanford University School of Medicine, Lauren teaches evidence-based medicine and holds a faculty appointment in the Division of General Medicine Disciplines in the Department of Medicine.

Selected Publications:

Maggio, L., ten Cate, O., Moorhead, L., van Stiphout, F., Kramer, M., ter Braak, E. Posley, K., Irby, D. & O'Brien, B. (2014). Characterizing physicians' information needs at the point of care. *Perspect Med Educ*. DOI: 10.1007/s40037-014-0118-z.

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