Learning progression from basic scientific scholarship to evidence-based medicine: a multimodal approach

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Author contributions: MB proposed the general outline of the paper based on (a) the developmental work of MG concerning the *Scientific Scholarship* theme in the Medical Degree Program at Lund University, (b) the collaborative work of MG and MB concerning aspects of the implementation of the theme across the Program, (c) MTP's work as head examiner of semester 2 and SR's work as course organizer of semester 8. MB coordinated the writing process. MG and MB wrote the drafts for Introduction, Methods and part of Results. MTP and SR drafted Examples 1 and 2. All authors contributed to the Discussion. Supplements 1, 2, 3A and 3B reflect the work of MB, MG, MTP and SR. All authors contributed to revisions of all parts of the manuscript.

Abstract

For the practicing physician, a critical, scientific and scholarly approach to medical knowledge and knowledge development is an imperative. Applying scientific scholarship is, therefore, a fundamental facet of the 'medical expert' or 'reflective doctor'. In the Medical Degree Program at Lund University, Sweden, a new *Scientific Scholarship* theme has been implemented, including evidence-based medicine, (EBM), as the application of scientific scholarship in EBM is a core aspect of medical education. The learning and practice of EBM depend on critical thinking, problem-solving, decision-making capabilities, basic skills in medicine and a basic scientific approach. To secure learning progression throughout the program, a combination of a modular and a longitudinal approach is used, alternately boosting and integrating the theme. The interdependent parts of the *Scientific Scholarship* theme allow students to build up skills progressively for later application in EBM, as shown in examples from semesters two and eight. Throughout the program, scientific scholarship and EBM are supported by multifaceted learning activities and structured assessment, ensuring that students work continuously and iteratively with these concepts. The theme also makes use of e-learning for written assignments and of *Cochrane Interactive Learning* modules together with locally developed e-lectures. We anticipate that the theme *Scientific Scholarship* will help our students to confidently use EBM and integrate a scholarly approach in daily practice whenever possible in their future role as 'reflective doctors'.

Scientific scholarship- why?

For the practising physician, a critical, scientific and scholarly approach to medical knowledge and knowledge development is an imperative. Regardless of whether 'factual evidence' is presented by colleagues, pharmaceutical companies, in the scientific arena, by the media or by well-read patients, a physician must apply a healthily sceptical attitude. Indeed, the 'scholar', implementing scientific scholarship, is considered a fundamental hallmark of the 'medical expert'.[1]

The Swedish Higher Education Ordinance defines twenty-three requirements for obtaining a Medical Degree and ten of these are related to scholarliness or a scientific approach to knowledge and knowledge development.[2] In accordance with international recommendations and these national requirements, *Scientific Scholarship* has been defined as one of six core themes of the Medical Degree Program at Lund University.[3] In the new curriculum developed to this end, the six themes together support the medical student's progressive transformation into a 'reflective doctor', with evidence-based medicine (EBM) constituting a particularly important aspect of the *Scientific Scholarship* theme (Figure 1).

The theoretical basis of *Scientific Scholarship* is similar to that of Scholarship of Teaching and Learning, SoTL, where research discovery, integration, application and use of research in teaching is central. [4] In addition, a number of activities in SoTL have similar counterparts in *Scientific Scholarship*, *e.g*. knowing the literature on teaching and learning, improving teaching and learning, monitoring students' learning results, communicating these results and critically reflecting within the teacher community and discipline.[5] The core skills of *Scientific Scholarship* are: knowledge of research methods, study design, statistics and how research is conducted, published, assessed and applied in clinical practice. Together with critical reflection, assessment and application of research results, the *Scientific Scholarship* theme forms an important part of the Medical Degree Program. The theme allows progressive training in research method application, knowledge assessment and synthesis and application of research results in clinical practice.

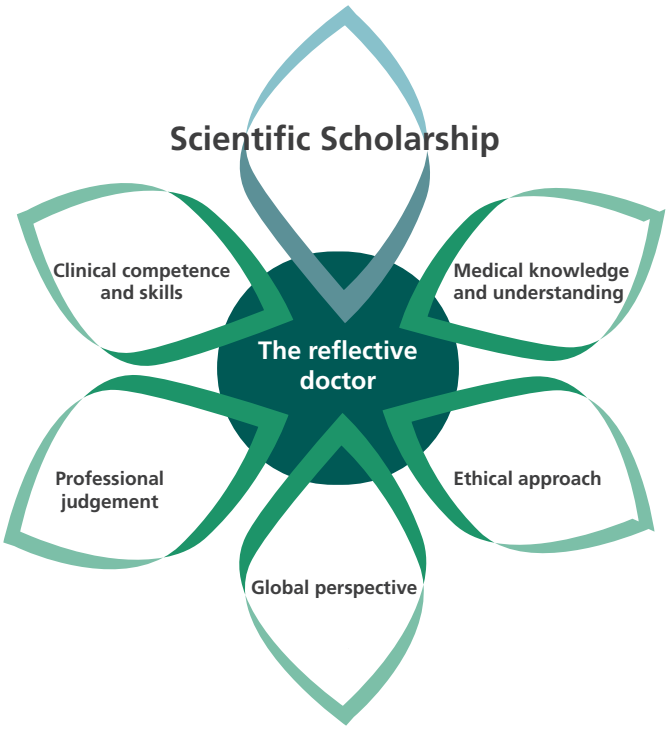

Figure 1. The 'reflective doctor'.
The concept 'reflective doctor' was launched as a part of the new Program syllabus of the Medical Degree Program at Lund University.[3] The 'reflective doctor' relies on a number of skills, supporting his/her medical decision-making. These skills are trained throughout the program within six 'core themes': *Scientific Scholarship, Medical knowledge and understanding, Ethical approach, Global perspective, Professional judgement, Clinical competence and skills*.

Healthcare staff in Sweden are legally bound to work in accordance with scientific evidence and established clinical experience[6]. Evidence-based medicine (EBM) is an application of scientific scholarship and a core aspect of medical education.[7-9] Teaching EBM provides opportunities to integrate students' knowledge in medicine with clinical reasoning, applying scientific scholarship to authentic, patient-relevant questions. There are several examples of how EBM is being taught – in-class or online, organized in modules or longitudinally. The emphasis given to EBM in the curriculum, and whether or not EBM skills are assessed, are factors that also vary in different implementations.[9-15] The learning and practice of EBM depend on a set of higher-order cognitive skills – critical thinking, problem-solving, and decision-making capabilities,[16] and require both basic skills in medicine and a basic scientific approach.[11] For efficient active learning, EBM should be integrated in clinical practice to ensure clinical relevance[8 17] and that students have the opportunity to interact with each other and with teachers in the learning process.[8 18] A longitudinal approach to scientific scholarship and EBM, where students work continuously and iteratively with the EBM concepts, is likely to increase learning progression.[19-22] A true learning progression, in turn, requires constructive alignment of learning objectives, learning activities and assessment, supportive infrastructure and continuous quality enhancement throughout medical training.[5 9]

Scientific scholarship- how?

To support the analysis, development, implementation and integration of scientific scholarship across the whole Medical Degree Program, a 25% teaching position as 'theme director' was appointed. In addition, teachers with relevant competencies across the program were engaged, and extensive support from specialized staff at the faculty library was secured (Supplement 1).

Before this development started, there was no explicit curriculum related to scientific scholarship in the Medical Degree Program. Learning activities and assessments that could be attributed to the theme were characterized by two pedagogical shortcomings – low frequency and lack of systematic learning progression throughout the program. To overcome these shortcomings, a framework for the new curriculum was created in three steps. First, the absolute level of the curriculum was adjusted to the ten requirements related to scientific scholarship for the Medical Degree according to the Swedish Higher Education Ordinance, which were used to define endpoint learning outcomes. Second, a progression of scientific scholarship learning outcomes across the program was created. By a design process that could be called 'inverse progression', the endpoint learning outcomes were gradually 'projected' backwards from the last semester through the whole program, decreasing the relative level of requirements semester by semester, all the way back to the introductory course. As a third step, the learning outcomes in each semester were used as starting point in a backward design, defining assessment criteria, assessment methods and learning activities for the specific semester.[23]

For flexibility, resource efficiency and ease of documentation, it was decided that learning activities related to scientific scholarship and EBM should rely partly on e-learning. With e-learning, students, teachers and clinicians can access the same resources at any time regardless of place at a self-directed pace. E-learning can have a positive effect on learning outcomes in EBM.[24-31] Since developing e-learning resources can be costly, and should be aligned with the learning objectives[32 33] the Faculty of Medicine initiated a collaboration with Cochrane. Cochrane's global work with systematic reviews for informed decisions in healthcare is considered a high-quality foundation for EBM. A Swedish node of Cochrane was launched in Lund in

2017. One of the outcomes of the collaboration was to integrate *Cochrane Interactive Learning* into the theme *Scientific Scholarship* in connection to relevant EBM learning objectives. The *Cochrane Interactive Learning* modules cover the process of how to conduct a systematic review, from formulating a question to finding, assessing and summarising evidence from studies. Each module contains videos, quizzes and exercises and an assessment that generates a certificate.[34] Students upload their certificates to the university's learning management system as part of the formal course assessment. The modules' contents are of high quality, the level is challenging and requires students to be engaged. The assessment tasks and modules can be revisited, which gives opportunity for repetition. The methodology of conducting a systematic review contains many elements that are necessary to master also for other evidence-based work relevant to students in their role as future physicians, such as clinical guideline development. Therefore, the Cochrane Interactive Learning modules were considered highly relevant to integrate in the Scientific Scholarship theme.

Progressing towards evidence-based medicine

In Supplement 2, learning outcomes related to the *Scientific Scholarship* theme and EBM across the Medical Degree Program, are outlined. The actual implementation of activities and assessments based on these learning outcomes follows a combined modular and longitudinal design, to achieve an alternation between 'boosting' scientific scholarship and 'integrating' it with medical and clinical topics. Accordingly, the whole second week of the 3-week Introductory course to medical studies is devoted to basic core methodology needed for scientific scholarship. The bachelor and master's theses in semesters 5 (10 weeks) and 10 (20 weeks), respectively, constitute such 'boosting' modules. In each of the semesters intercalated between these three modules, roughly 1/20 of the credits are dedicated to scientific scholarship, in total corresponding to 10 weeks across the program. Here, scientific scholarship is thoroughly integrated into activities and assessments related to the core topic of each semester, to achieve synergistic effects with students' development of medical knowledge and clinical skills.

Figure 2 illustrates how the necessary building blocks for an endpoint learning outcome – "critically review and discuss whether a scientifically based recommendation is applicable to the specific individual patient" – are progressively achieved, using elements from basic science to clinical courses.

The learning progression is designed to gradually introduce concepts on a level where students are ready to understand and apply them. Later on, the concepts reappear, in a more advanced form or with additional applications, to support learning progression from basic science to a clinical setting. Sequencing the learning outcomes and gradually increasing the level of difficulty supports learning progression, where increased breadth and depth in knowledge and skills supports increased utility, application, proficiency and accomplishment.[35] The sequenced progression of the learning outcomes described in Figure 2 also corresponds to the SOLO (Structure of Observed Learning Outcomes) taxonomy of learning outcomes[5].

As shown in Figure 2, the theme starts on a basic level, where understanding the structure and content of original research papers is the first step, advancing to summarizing research papers and so on. In semester five students write a bachelor thesis. Semester five also focuses on research methods, study designs and statistics, where students gain deeper understanding in these areas and how to apply them. The clinical semesters (semester six and forward) introduce EBM concepts, which are applied in a clinical context where

Figure 2

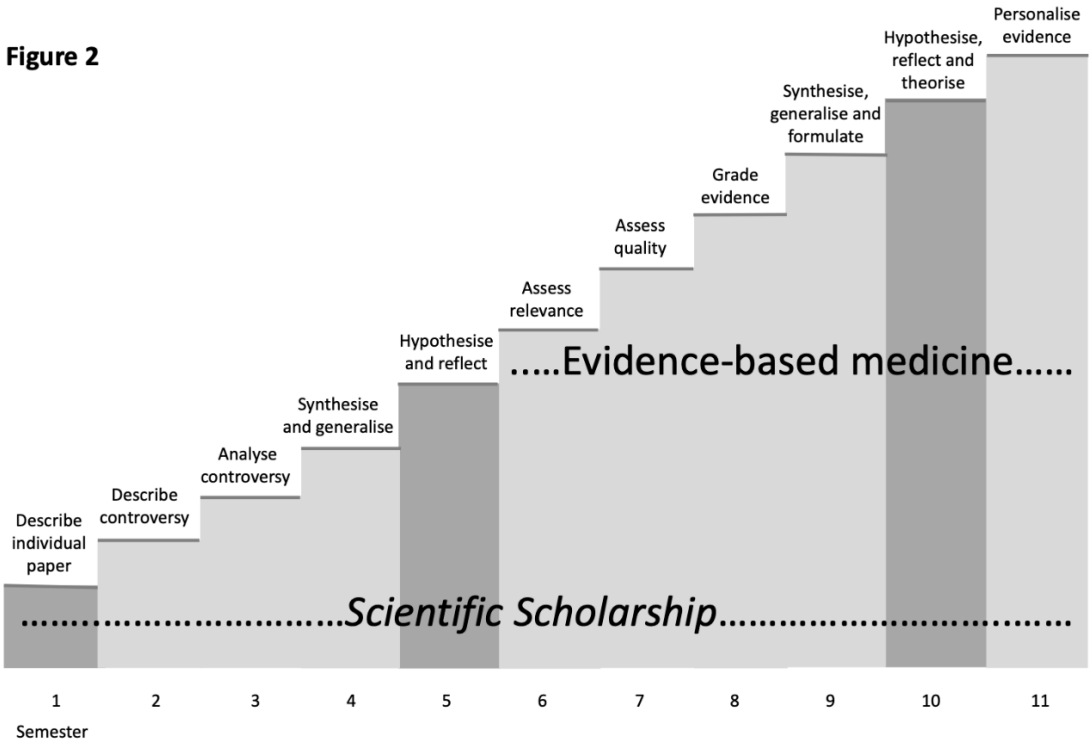

Figure 2. Learning progression from *Scientific Scholarship* to Evidence-based medicine (EBM).
The alternating modular and longitudinal design is indicated by different shades: 'boosting' scientific scholarship (dark grey) and 'integration' with medical and clinical topics (light grey).

students work with authentic patient-related research questions, including searching for, assessing and grading evidence of research papers to answer the question. In their master thesis at semester ten, students are expected to independently apply the concepts they previously worked with within the theme Scientific Scholarship, to their thesis. The final step is to apply and communicate EBM to specific patients based on the patient's individual needs.

Integrating research into undergraduate education is important to make students understand and apply research principles. Student projects such as a bachelor or master theses are naturally integrated with the use of research, but research integration can be achieved on many levels. [36] The use of original research papers plays an important part in the theme *Scientific Scholarship*, since this format of publication is the most common in medicine. Articles are usually peer reviewed and reading articles is also a way for students as future physicians to keep up-to-date with research findings. Many other sources of essential for students develop an understanding of their structure and content. Students also need to practice how to independently find, assess and grade the evidence as well as summarizing research papers, as a part of EBM. Many of the learning activities in the theme evolve around these aspects of original articles to support students' learning and prepare them for future clinical evidence-based work.

The development and implementation of the *Scientific Scholarship* theme is a long-term process. Assessing students' knowledge, skills, attitudes and behaviour in *Scientific Scholarship* and EBM is also a long-term process, where we have a multimodal approach to assessment activities to cover as many learning domains as possible. Previous findings support a multimodal approach for both learning activities and assessment, in the teaching of EBM[19 30 31 37 38] and it is reasonable to assume this is also a relevant strategy for the Scientific Scholarship theme. The learning progression is designed to introduce concepts

to students gradually and progressively, and future evaluation will show if this strategy has led to the intended learning outcomes. Long-term follow-up and evaluation are necessary when the Scientific Scholarship theme, including EBM, is fully implemented. In our setting, learning analytics from multiple learning management systems and modules, together with student and teacher evaluations can be valuable components in a future long-term evaluation of the outcomes.

Here, two examples of learning activities and associated assessments at different stages of the Medical Degree Program are presented. In the first, students approach the subject of controversies in medical science, one of many elements of *Scientific Scholarship.* The second illustrates applied activities in a clinical setting, focusing on EBM. Both constitute steps in the learning progression illustrated in Figure 2. Additional information is available in Supplement 3.

Example 1: Scientific controversy in the second semester

In the second semester of the Medical Degree Program, the assignment relating to *Scientific Scholarship* examines scientific controversy. The aim is to create a platform to discuss the dynamics of medical knowledge as constantly evolving and how, in this process, conflicting data can emerge. Another goal is to prompt the students to reflect upon how scientific controversies not only fuel knowledge development, but also can challenge scientific credibility. In this sense, scientific controversy is an essential building block of *Scientific Scholarship* and the concepts that the students encounter during their basic science semesters concerning controversies in medical science are of great use when applied in a clinical context.

In this semester, our students are taught *anatomy and physiology of the nervous system* and attend a workshop on *mental health first aid*. Addressing the concept of scientific controversy at this point seems adequate, as the students are introduced to scientific publications already during the first semester and, notably, given that precious studies have shown that basic neuroscience principles may be successfully taught using articles demonstrating scientific controversies.[39 40]

The first time the assignment relating to scientific controversy was introduced to our students, they were presented with two articles addressing the issue of whether and how two neuropsychiatric disorders - autism and schizophrenia - are related. The studies have different standpoints in approaching the relationship between the two disorders, use distinct methodologies and come to different conclusions. Our initial expectation was that, despite the students' lack of academic knowledge and of clinical experience of the topic, the publications were well aligned with the medical subjects of the semester and would expose our students early in their education to scientific research related to clinical neurosciences.

For the assignment, the students were required to answer questions related to the articles and provide an account of the literature search strategy they used to identify additional publications in the field to put the controversy in context (Supplement 3A).

In an evaluation of essays submitted over two consecutive academic semesters, students showed that they were aware of the occurrence and implications of controversy in medicine and many produced outstanding reflections on the topic. At the same time, the majority of the students were unable to answer questions about the methods employed in the two studies or to motivate the choice of methodology. As indicated in the guidelines given to the students, the questions should be answered having in mind a group of fellow students as the audience. We anticipated that the students would describe in general terms what types of analyses were performed and why. Instead, many students

merely listed the methods employed, despite being instructed not to rely on direct translations of the original articles.

Our initial observations with the assignment pointed to a mismatch between our evaluation criteria and the students' cognitive readiness to perform the task. In the second semester, most of our students do not yet have any background knowledge of the topics of the two publications and have very little previous experience of experimental or clinical work in the area. We have not performed a survey among the students about how they perceived the assignment and have only gathered informal input about what, in their view, can or should be improved. Nevertheless, our examination of the assignment confirmed that questions concerning methodologies need to be either supported by complementary material and/or a lecture, or need to be adapted to the appropriate level of knowledge, revolving, in the second semester, instead around e.g., parameters and variables analysed, sample sizes, experimental groups, ethical aspects etc.

During the autumn semester of 2020, two new articles were provided to the students, which describe phenomena that the students are taught during the *physiology of the nervous system* course, namely the occurrence or not of neurogenesis in the adult human brain; the articles also refer to cellular processes that were introduced in the first semester and to brain areas that become known to the students in the second semester. The main novel component in the two studies revolves around the methodology used, which expands on concepts previously introduced during the first semester. In addition, more detailed instructions concerning the different parts of the assignment were provided.

In a first evaluation of the new submitted essays, it seems that the students were indeed better equipped to perform the assignment. One of the points in the evaluation, for instance, asks students to determine in which way the methods utilized in both studies test their hypotheses, to give us an indicator that the students in effect understand the studies' overall purpose, structure, results and conclusions". A great majority of the students seem to have had no problem with this analysis. The new version of the assignment has, therefore, attained to a much better extent the intended double benefit of stimulating knowledge and interest in neurosciences and awareness about the value of scientific rationality and of how opposing scientific results impact our knowledge and understanding. It also confirmed that for learning progression to be effectual, there needs to be a good alignment between the education and information the students are provided and the skills expectations and assessment.

Another important observation made relates to the instructions to the assessors. It is our experience that it is not sufficient to itemise the assessment criteria and essential qualities that the assignment needs to meet. Although the selected assessors have the required competencies, it is necessary to discuss each of the guidelines with the group of assessors to ensure objectivity and consistency in the assessment process. A meeting with all assessors was arranged in the fall of 2020, which appears to have contributed to a much better calibration of the evaluation criteria.

Example 2: EBM portfolio in the eighth semester

The eighth semester includes seven surgical disciplines. Almost 20 years ago, interested teachers noticed that questions from students often related to lack of EBM in clinical decision making.[41] Consequently, a portfolio including a critical review of a surgical paper and grading of evidence for a specific clinical question was introduced. Students' evaluation concluded that although the tasks were interesting, they were hard to complete and induced a high level of stress. The EBM portfolio was then

reduced, and students had to formulate a question based on an authentic clinical situation, make an adequate literature search and select papers relevant to their question. To answer the question, they had to read the papers, grade the evidence and present them.

When the new curriculum with the *Scientific Scholarship* theme was introduced, the EBM portfolio was further developed. In collaboration with the theme director, the portfolio was made more concise and better aligned to specific learning objectives that fit with a progression across adjacent semesters. The evidence grading assignment was better structured and students are now required to present a table with a summary of findings and motivate their conclusions. Furthermore, relevant modules of *Cochrane Interactive Learning* were added as learning activities for systematic assessment of students´ methodological skills in EBM. Other e-learning activities include e-lectures explaining the process of evidence grading, using checklists from the Swedish Health Technology Assessment and Assessment of Social Services.[42] Initially, after this implementation students required more personal guidance with librarians and webinars to complete the task. Eventually, as EBM-related tasks have been integrated in earlier semesters, students have become more prepared and need less supervision. Assessment of EBM includes specific multiple-choice questions in the written assessment and EBM discussions in case sessions. A specific assessment form has been introduced, helping teachers with the grading of the portfolio (Supplement 3B). Teachers report that the EBM report is now easy to grade. This multifaceted approach to learning and assessment activities has helped increase the impact of EBM and helped students to better understand how to implement the process of EBM.[21 30] Overall, students´ evaluations show less stress for the EBM portfolio when EBM is an integrated part of the curriculum throughout the program, despite the higher workload.

What next?

In our experience, developing and implementing scientific scholarship and EBM, and evaluating student performance, is a long-term process. It requires a combination of a modular and longitudinal approach that include multifaceted learning and assessment activities, in order to ensure learning progression. It is also crucial that students early in the program understand why they need to combine medical knowledge with a scientific approach. We have observed that students need training to acquire basic concepts in research methods to be able to apply these later, in accordance with previous findings.[11] Likewise, our experience is that students need multifaceted learning activities to understand how to apply EBM concepts such as evidence grading, as emphasized in the literature.[21 30] The examples of implementation at semester two and eight owe their success to engaged teachers working systematically over time, together with specialized library staff. Our implementation of the *Cochrane Interactive Learning* modules where they match the learning objectives is successful, in line with previous findings.[32 33] Together with locally developed e-lectures and specialized library support students get additional context and examples. Collaboration with an evidence expert organization, such as Cochrane, give students authentic and international context together with an understanding of the importance of systematic reviews in EBM. This has led to a significant increase in the number of students performing a systematic review as their master thesis.

There are also remaining challenges regarding the theme *Scientific Scholarship*. The Medical Degree Program runs across three campuses simultaneously, and engaging teachers who are also busy clinicians or researchers can be difficult. It is also clear that if teachers take part in developing instructions for learning and assessment activities, compliance with these instructions increases. Making teachers

confident about teaching EBM is important. To this end, the *Cochrane Interactive Learning* modules have been made available also to teachers, as a way of creating teacher engagement. Our collaboration with the faculty library has also greatly facilitated the development and implementation of e-learning resources, helping teachers to implement EBM methodologies. The *Scientific Scholarship* theme has also created opportunities for collaboration between teachers from different disciplines. The collaboration helped the constructive alignment of learning and assessment activities, and created a forum where knowledge gaps and pedagogical challenges can be discussed openly. The *Scientific Scholarship* theme needs to be continuously evaluated to ensure that the learning and assessment activities are appropriate to meet the intended learning progression, not only as outlined by the stipulated learning outcomes, but also in practice. A long-term evaluation is also needed to assess whether the progression and outcomes works as intended, and if there are parts of the theme that should be developed further. Here, learning analytics are important but also the use of other methods to reach out to students and teachers to collect their experiences and suggestions for further development. A long-term evaluation will provide valuable data not only for the Medical Degree Program at Lund, but also for other universities, since there are few long-term evaluations to date.[30 37] Another challenge would be to follow up if students are continuing to apply the concepts from *Scientific Scholarship* and EBM after graduation, in their daily clinical practice. This is difficult to do, but would also shed additional light on the outcomes of the theme Scientific Scholarship and whether it makes a difference in students' knowledge, skills and behavior. The complexity of integrating EBM into daily clinical practice remains challenging. However, our experience is that knowledge gaps in clinical practice can motivate students as well as teachers - who are busy clinicians or researchers- to find, critically appraise, reflect upon and use evidence. We believe that our continuous work with the theme *Scientific Scholarship* will help students integrate a scholarly approach and confidently use EBM in daily practice whenever possible as future reflective doctors.

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SUPPLEMENT 1

Description of specialized support from Library & ICT, Faculty of Medicine, Lund University

Finding, assessing and using information plays a vital role in scientific scholarship and evidence-based medicine (EBM) and students need continuous training to understand and apply these concepts.[21] Appreciating the constant development of medical knowledge, why and how scientific controversies occur, and how to stay up to date are important aspects of scientific scholarship and EBM, all fundamental for the process of becoming a 'reflective doctor'. Here, medical librarians are important partners in developing relevant learning and assessment activities, facilitating the implementation of and access to learning resources and support. Medical librarians are experts in information management and can often provide tailored support and instructions for students and teachers in EBM methodology.[20]

The process of developing learning activities, resources, assessment and support in scientific scholarship and EBM in the Medical Degree Program at Lund University was a collaborative process where the theme director involved specialized library staff from the start. Progression, intended learning outcomes, pedagogical challenges and resource considerations were discussed, among other challenges and opportunities. Multifaceted learning activities, lectures, workshops, e-lectures and webinars, one-to-one guidance sessions were developed by the library, tested and evaluated together with the theme director, teachers and students. The library provides support to the Cochrane Interactive Learning modules, from registration to questions regarding content, in collaboration with Cochrane. The library also contributes to different assessment formats such as MCQs and the requirements for students' written assignments. The learning activities across the theme are described below.

Support to the *Scientific Scholarship* theme and EBM from the Medical Faculty's Library & ICT

Semester	Scientific Scholarship learning outcomes (in concordance with Supplement 2 and Figure 2)	Learning support and activities from the library
1	Describe individual paper	− Lecture: medical information sources − Workshop: how to read a paper, IMRAD structure and context of papers, interactive exercises using polling tool. − Extra reading material
2	Describe controversy	− Lecture: introducing basic skills in structured information searching, putting scientific controversy in context of a constant development of knowledge − Introduction to PubMed and search strategies including MeSH terms and free text words
3	Analyse controversy	− Students apply skills acquired in previous semesters
4	Synthesise and generalise	− Students apply skills acquired in previous semesters

5	Hypothesise and reflect	– Bachelor thesis – Structured information searching in multiple databases, – Lecture and workshops: introduction to evidence hierarchy – Lecture: Copyright, scientific publishing and scientific conduct – Workshop: Reference management and EndNote – One-to-one guidance sessions
6	Assess relevance	– Cochrane Interactive Learning modules – Videos introducing EBM, structured information retrieval revisited, relevance assessment – One-to-one guidance sessions
7	Assess quality	– Cochrane Interactive Learning modules – Video on quality assessment – One-to-one guidance sessions
8	Grade evidence	– Cochrane Interactive Learning modules – Video on evidence grading – One-to-one guidance sessions
9	Synthesise, generalise and formulate	– Cochrane Interactive Learning modules – Project plan for master thesis – support under development
10	Hypothesise, reflect and theorise	– Master thesis – Lecture and workshops: Structured information searching in multiple databases, evidence hierarchy and evidence assessment, Reference management and EndNote – One-to-one guidance sessions
11	Personalise evidence	– Support under development

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SUPPLEMENT 2 Learning outcomes of semesters 1-11 (S1-S11) in the Medical Degree Program at Lund University, representing four aspects of scientific scholarship. DP1/2: Degree projects 1 and 2, bachelor and master theses respectively. Followed by T denotes Theory, P denotes Project.

	Scientific information: searching and assessing	**Scientific communication: content and form**	**The scientific process: rationale and methods**	**Science ethics**
INTRO	– account for differences between different types of medical information sources	– describe the outline of a scientific article and the principle contents of its various parts – report the contents of a scientific article to a layman, orally in Swedish – discuss how medical scientific findings may be represented in the media	– account for the concepts causality and hypothesis testing	
S1		– account for the content of a scientific article through a written report in Swedish addressed to fellow students	– identify the scientific question and the scientific and analytical methods in a scientific article	
S2	– search for scientific articles in a medical database in a structured way, using basic search techniques	– account for a scientific controversy, in writing in Swedish	– describe scientific and analytical methods and explain how choice of methods is motivated by the scientific question at hand in scientific articles	– identify ethical considerations in scientific studies
S3	– search for scientific articles in two different medical databases, in a structured way, using basic search techniques	– discuss a scientific controversy, orally in English	– discuss scientific and analytical methods, results and conclusions in relation to the scientific question at hand in scientific articles	– describe ethical considerations in scientific studies
S4	– search for scientific articles in several different medical databases, in a structured way, using advanced search techniques		– explain the limitations of various diagnostic analyses based on the underlying scientific methods and	– discuss ethical considerations in scientific studies based on basic research ethical concepts and principles

			how these limitations affect the interpretation of analysis results – explain how diagnostic analyses are evaluated, what statistical parameters are used in the evaluation and how these parameters can vary between different patient populations	
S5	– under proactive supervision, formulate a specific scientific question based on the current state of knowledge – under proactive supervision, write a project plan with appropriate study design for a degree project based on the overall purpose and the scientific question			
DP1T	– apply appropriate search strategies when searching for scientific literature – apply concepts and principles of relevance to systematic literature search – apply principles for relevance assessment, quality review and evidence grading of scientific articles using templates	– apply basic concepts and principles regarding reference management and disposition of scientific articles – apply basic copyright concepts and principles	– describe methods applicable within a defined part of the medical field and the possibilities and limitations of the methods – explain basic concepts and principles regarding quantitative studies and qualitative method – explain the rationale of clinical trials and explain the laws and regulations governing such trials – apply basic concepts and principles regarding study design, statistics and epidemiology	– apply research ethical concepts, principles, laws and regulations

DP1P	– based on a specific scientific question independently search, select and evaluate sources and use information from the literature in a degree project and in discussion with fellow students	– account for the current state of knowledge and for current research in a limited part of the medical field – write a scientific essay in Swedish or English and a popular scientific summary of it in Swedish – describe and discuss own degree project, orally in Swedish – assess fellow students' degree projects by critically reviewing and providing constructive feedback	– describe scientific methods applicable to the degree project and, based on the possibilities and limitations of the methods, explain choice of methods – carry out a project based on the project plan, compile and analyse results and critically evaluate the significance and limitations of these based on the scientific question and methods – assess own knowledge gaps and take responsibility for own knowledge development in the field of the degree project	– make judgments regarding research ethical aspects with specific relevance to the degree project
S6	– conduct a systematic search and relevance assessment of the scientific literature based on a specific clinical question	– summarize to fellow students, in writing and orally, relevance assessed scientific literature based on a systematic search	– under proactive supervision, formulate a specific clinical question based on authentic patient cases	
S7	– conduct a systematic search, relevance assessment and quality review of the scientific literature based on a specific clinical question	– critically report to colleagues, in writing and orally, quality reviewed scientific literature based on a systematic search	– under reactive supervision, formulate a specific clinical question based on authentic patient cases	
S8	– conduct a systematic search, relevance assessment, quality review and evidence grading of the scientific literature based on a specific clinical question	– explain, in writing and orally, in a doctor-patient setting, key findings from evidence graded scientific literature based on a systematic search	– independently formulate a specific clinical question based on authentic patient cases	

S9	– under reactive supervision, formulate a specific scientific question based on the current state of knowledge – under reactive supervision, write a project plan with appropriate study design for a degree project based on the overall purpose and the scientific question			
DP2T	– under development			
DP2P	– based on structured search strategies independently identify, select and evaluate sources and use information from the literature for the implementation of a degree project and in discussion with fellow students	– give an in-depth account of the current state of knowledge and of current research in a defined part of the medical field – plan and independently write a scientific essay in English and a popular science summary in Swedish – give an independent oral account, in English, and discuss the degree project and the knowledge and arguments on which it is based, in dialogue with both researchers and fellow students – critically review and, on a scientific basis, provide constructive feedback to fellow students regarding their degree project, in English, both orally and in writing	– discuss scientific methods applicable to the field of the degree project, the possibilities and limitations of the methods used and argue for the selection of methods relevant to the degree project – implement a project based on a project plan, collect data, analyse results and independently compile and critically evaluate their importance and limitations based on the research question and methods used – assess own knowledge gaps and take responsibility for own knowledge development in the field of the degree project	– independently assess ethical issues with consideration of research ethical principles with specific relevance to the own and fellow students' degree projects
S11	– critically review and discuss whether a scientifically based recommendation is applicable to the specific individual patient			

SUPPLEMENT 3A

Relevant background: During the first semester, students learn to characterise the various parts of a scientific article, to identify the scientific question and the scientific and analytical methods and to give a report of an article. The concepts “causality” and “hypothesis testing” are integrated in this process (Supplement 2).

Description of the scientific scholarship portfolio in the second semester, including assessment form

In the second semester, as a crucial step in understanding the nature of science and knowledge development, students come in contact with the concept of scientific controversy. In a lecture, various principal causes that may underlie a controversy – different formulations of the scientific question, different methods used, different interpretations of findings, different levels of analyses are discussed. An instructional lecture also introduces the students to methods of structured literature search, how to find papers related to a specific topic. The students are subsequently requested to read two pre-assigned articles published in international journals that examine the same scientific question but arrive to opposite conclusions. For the assignment, the students need to answer a few questions relating to the content of the articles, give an account of the scientific controversy and do a literature search expanding on the topic, while following general and specific guidelines for written assignments. The assessment is performed by a reviewing group of teachers associated with the second semester that evaluate how the students perform the following tasks using a specific form:

Scientific portfolio assessment form	
General requirements	− Are the general guidelines for written assignments being followed?
Assignment requirements	− Are the guidelines for the specific assignment being followed?
Title in Swedish	− Does the title provided reflect the content of the articles and the scientific controversy and elicits interest?
Purpose and scientific controversy	− Are the purposes of the two studies and the primary scientific controversy identified and appropriately described?
Study design	− Are the distinctive perspectives and study designs employed in the two articles well outlined?
Research methodology	− Are the main methodologies utilised in the two articles and the rationale for the use of the specific methods adequately described?
Ethical aspects	− Have relevant ethical aspects been identified and analyzed?
Reflection	− Is there a personal analysis about the positive and negative impacts of scientific controversies?
Literature search	− Are the search terms and databases used described?

	– Is there a detailed description of the search methodology, including MeSH-terms and free text terms, and motivation for the chosen search strategy?

SUPPLEMENT 3B

Relevant background: During the two preceding semesters, students are introduced to and practice how to conduct a systematic search, relevance assessment and quality review of the scientific literature based on a specific clinical question. In addition, various communication skills are practiced and assessed in the context of reporting their findings.

Description of the EBM portfolio in the eighth semester, including assessment form

One of the qualitatively important steps in EBM learning progression in semester eight concerns evidence grading. In the first week of semester eight, students get a short introductory lecture on learning objectives (Supplement 2), assessment and learning activities. They are advised to independently formulate a unique and specific clinical question during their clinical placement in surgery. Students are recommended to formulate their question rather concisely and to specify patient cohort as well as outcome to make the literature search and evidence grading more explicit. Good examples of previously used questions such as "Does treatment with antibiotic reduce number of complications for patients with mild diverticulitis?" are given.

In the portfolio, students describe their question, in which clinical situation they identified/formulated this question and why they chose it. A short background of the specific clinical topic should be included. In the next step, students describe their literature search including database, search words, number of hits, and use of filters. The selection of papers should be transparent and well described in the portfolio, easy for the reader to follow. For grading of evidence students use the GRADE system and specific checklists from the Swedish Health Technology Assessment and Assessment of Social Services[41]. In a result section, students report their quality review, which must include a table for grading of evidence. Finally, students conclude their key findings and the strengths of evidence for the answer to their question. Altogether, the assignment is 2-3 A4 pages. Teachers grade the portfolios using a specific assessment form:

	Scientific portfolio assessment form
Clinical question	– Is it a scientifically and clinically relevant question? – Does the description of the clinical situation support that the question is authentic?
Background	– Is the description of the clinical background relevant and correct?

Literature search and selection of papers	– Are search terms and database described? – Is the search correct and in alignment with the question? – Is it possible to follow the search strategy and the selection process? – Are the relevant papers selected?
Quality review	– Are papers adequately analyzed? – Is the number of studies correct (minimum 3)? – Are original papers used for evidence grading?
Grading of evidence	– Is the grading of evidence correct and presented in a table for grading of evidence?
Conclusion	– Is the conclusion correct and communicated?
Overall	– Are references used adequately? – Is the assignment 2-3 A4 pages long?

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