Integration and timing of basic and clinical sciences education

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Abstract

Background: Medical education has traditionally been compartmentalized into basic and clinical sciences, with the latter being viewed as the skillful application of the former. Over time, the relevance of basic sciences has become defined by their role in supporting clinical problem solving rather than being, of themselves, a defining knowledge base of physicians.

Methods. As part of the national Future of Medical Education in Canada (FMEC MD) project, a comprehensive empirical environmental scan identified the timing and integration of basic sciences as a key pressing issue for medical education. Using the literature review, key informant interviews, stakeholder meetings, and subsequent consultation forums from the FMEC project, this paper details the empirical basis for focusing on the role of basic science, the evidentiary foundations for current practices, and the implications for medical education.

Findings: Despite a dearth of definitive relevant studies, opinions about how best to integrate the sciences remain strong. Resource allocation, political power, educational philosophy, and the shift from a knowledge-based to a problem-solving profession all influence the debate. There was little disagreement that both sciences are important, that many traditional models emphasized deep understanding of limited basic science disciplines at the expense of other relevant content such as social sciences, or that teaching the sciences contemporaneously rather than sequentially has theoretical and practical merit. Innovations in integrated curriculum design have occurred internationally. Less clear are the appropriate balance of the sciences, the best integration model, and solutions to the political and practical challenges of integrated curricula.

Discussion: New curricula tend to emphasize integration, development of more diverse physician competencies, and preparation of physicians to adapt to evolving technology and patients' expectations. Refocusing the basic/clinical dichotomy to a foundational/applied model may yield benefits in training widely competent future physicians.

Practice Points

Framing medical education as 'basic' plus 'clinical' sciences is anachronistic and does not acknowledge the breadth of physician competencies.

Rather than only some sciences being 'basic', all science domains (including social sciences) have basic and applied components.

A new dichotomy of 'foundational' and 'applied' should be adopted for medical education.

Integrating foundational and applied learning over time may maximize student engagement and knowledge retention.

Introduction.

As part of the Future of Medical Education in Canada (FMEC) initiative, the Association of Faculties of Medicine in Canada (AFMC) undertook a national environmental scan to determine the current state of Canadian medical education and establish directions for future evolution of the system. Through an extensive review of the literature augmented by key informant interviews and broad consultation, this initiative was to result in recommendations for improving medical training that address: a) priorities and challenges facing medical education in Canada, b) innovations which are emerging in response to these challenges, and c) factors that facilitate or hinder the evolution and adaptation of medical education in Canada. The timing and integration of basic sciences into medical curricula arose as an important issue with significant impact on medical teachers' practice and identity. The environmental scan process was able to explore, from varying perspectives, how these issues uniquely manifest in a Canadian context and how this relates to international discourse.

For much of the last century, medical education has been conceptualized as training compartmentalized into the basic sciences and the clinical sciences (to which we refer in this paper as the 'two sciences'). Described as a '3+1' model (3 years of basic sciences and another of clinical experience to learn application) by Flexner (1910), this dichotomous approach has persisted with a '2 + 2' format eventually becoming the norm in North America. Other jurisdictions maintained the 'basic plus clinical' model, but incorporated differing balances between prerequisites and core medical training (e.g. admission after secondary school with full inclusion of basic sciences in medical school vs. admission to medicine after some basic science at the undergraduate level). (Flexner 1910) While Flexner (1910) is strongly associated with

training focused on basic sciences as a foundation in a bioscientific model, he clearly acknowledged that basic sciences alone were not sufficient preparation for future physician practice. (Cooke et. al. 2006, Flexner 1910, , Flexner 1925) Furthermore, what constitutes 'basic' sciences has been expanded somewhat over the course of the century. Typified in Flexner's era by content areas aligned with traditional academic departments and amenable to teaching in lecture or laboratory formats, basic sciences were seen to include anatomy, biochemistry, biology, chemistry, pathology, physiology and the like. Since then, permutations such as pharmacology and more recently new domains including social sciences (for example communication skills) and epidemiology have been added. (Laidlaw & Hart 2011, Mandin 2000, Shield et al. 2011). Clinical sciences in contrast are more nebulous, seen to involve diagnostic reasoning, interprofessional collaboration skills and practical problem solving; and are oft felt to best be taught at the bedside in the context of patient care (or more recently in simulated care scenarios). Even in current innovative systems that seek to integrate these two sciences through vertical (across time), horizontal (across subject matter) or spiral (learning both sciences across both time and subject matter) integration, the distinction between the two is still maintained. (Barrows & Tamblyn 1980, Elliott 1999, Gatenby & Martin 2009, Prideaux 2001) The 2009 Association of American Medical Colleges/Howard Hughes Medical Institute consensus document states, "The desired outcome of the medical education process should be scientifically inquisitive and compassionate physicians who have the motivation, tools, and knowledge to find the necessary information to provide the best and most scientifically sound care for their patients. As such, the medical school curriculum should be integrated across disciplines and repeatedly emphasize the importance and relevance of the sciences basic to medicine."

While sound knowledge of basic sciences was once seen as a defining characteristic of doctors, the necessary scope of basic sciences knowledge for doctors has evolved to be defined more and more as the minimum required to solve clinical problems. (Ginexi 2006, Glew 2003, Irby & Wilkerson 2003). Proponents of this evolution argue that basic sciences have little actual or perceived relevance when taught outside of a clinical context, making learning more difficult from the learner's perspective. (Barrows & Tamblyn 1980, Norman & Schmidt 1992) Furthermore, the use of basic sciences by practicing physicians has been shown to be limited (Patel et al. 1988). Opposing views counter that learning is different from practice, that a sound understanding of basic sciences is critical to the successful development and application of clinical knowledge, and that basic science is most efficiently incorporated into short term memory when learned in isolation from manipulation and application. (Glew 2003, Kirschner et al. 2006, Woods et al. 2005). This paper provides a detailed synthesis of the data generated in the FMEC environmental scan relevant to these ambient issues and discusses their importance for both the Canadian medical education context and the field more broadly.

Methods

The FMEC environmental scan was undertaken as a research project to inform a later policy-making, strategic planning process and was approved by the Research Ethics Boards of the University of Toronto and l'Université de Montréal. The data collection occurred in three inter-related phases: A series of literature reviews, key informant interviews, and three expert panel focus groups.

National Key Informant Interviews

Thirty participants were purposively selected to represent a breadth of perspectives and stakeholder groups related to Canadian undergraduate medical education. These included academic leaders (n=6), leaders of health care and/or education programs and institutions (n=7), health or education government officials (n=3), academic leaders from health professions outside medicine (n=5), and various other representatives such as from medical professional organizations, medical education journals, and interested engaged public members (n=9). Participants represented a breadth of geographic, age, gender and linguistic diversity within Canada. Current medical school deans were excluded as participants because they were to be involved later in the AFMC's policy-making process.

Telephone interviews were semi-structured, scheduled for sixty minutes and conducted by a member of the research team experienced in qualitative interviewing. Each participant was asked to use their own perspective to identify and describe opportunities, barriers and existing innovations related to 'the three to five most important challenges to be met by Canada's faculties of medicine, given their social responsibility to train the next generation of physicians'. Interviews were transcribed and sent to the interviewees for approval. Participants granted permission to **analyze and report** the results of the interviews in a non-anonymized fashion.

Literature Reviews

The research team and the AFMC project steering committee identified a list of thirty important and/or timely topics related to undergraduate medical education. Structured literature reviews were commissioned on each topic from primarily Canadian authors with expertise in these areas. Brief synthesis reviews were requested for topics for which there had been either a recent review in the published literature or a sparcity of literature, and longer reviews commissioned for the

remaining topics. The final reviews were appraised by the rest of the research team and the AFMC project steering committee and in some cases by outside experts. Papers were revised if necessary for quality and rigour. In total, sixty-two authors produced thirty-four reviews totalling 550 pages of data. (Over the course of data collection for the environmental scan, other topics were identified that required review and four additional reviews were commissioned.)

Expert Panels

The AFMC project steering committee organized three expert panels to serve as focus groups to identify further issues and themes related to undergraduate medical education from their various perspectives. These AFMC-organized panels were: the Young Leaders Forum (comprised of involved learners and junior faculty members in the health professions, the Blue Ribbon Panel (comprised of accomplished, recognized public members), and the Data Needs and Access Group (comprised of analysts, researchers and policymakers). All of these groups are described in detail on the AFMC's website (AFMC 2010). Members of the research team observed each of the panels and helped draft the resultant reports.

Data Coding & Analysis

Data from the key informant interviews were analysed using three-phase inductive thematic content analysis to ensure an accurate, comprehensive representation of participants' issues and priorities was brought forward. Thematic categories were developed based on the challenges, opportunities and barriers identified by participants. These categories were then used to vertically analyze each interview. Data was compared transversally (across participants). Each transcript was iteratively coded by one member of the research team and a comprehensive, 77-page codebook was developed. A second member of the team independently coded several transcripts as a check for consistency. Finally, five research team members with different

professional and academic perspectives validated the codebook by recoding selected interviews and examining quotations attributed to each code; discrepancies were addressed by consensus.

The commissioned literature reviews were each coded for keywords related to content areas. These were indexed electronically for ease of access. The data from the expert panels were collated into a series of reports describing the emergent issues and themes from the discussions.

Data Triangulation & Synthesis

Nineteen people from the research team and the AFMC project steering committee worked in three randomly assigned groups to synthesize the data. Each person read the entire interview codebook and the quotations attributed to each code, all the literature reviews and all the expert panel reports. Each group independently identified the six to twelve most prominent themes they felt were represented in the data. Participants were encouraged to be reflexively mindful of their own subject-positions with respect to the data and to draw out multiple perspectives rather than only the most common ones. Each group's list was presented to the entire synthesis team. There was over 80% overlap between these lists and they were merged, by consensus, into a single listing of ten priorities for undergraduate medical education in Canada. All ten empirically-derived consensus priorities and a more detailed account of the project's methodology has been previously published (Hodges et al. 2011) as has the final AFMC FMEC MD project summary report (AFMC 2009). The data pertaining to the timing and integration of basic sciences was systematically extracted from the overall data set and further triangulated with relevant literature by the authors to form the basis for this paper.

Findings.

The findings derived from the comprehensive data set are summarized here. Key themes related to the role of basic sciences were identified from the literature scan and contextualized through quotes from interviews and excerpts from the expert groups. Implications for the international education community and further relation to selected literature is provided in the discussion section.

The basic and clinical conceptual dichotomy

Participants in the FMEC project spoke with familiarity of the two groups of sciences. There was broad acceptance of the concept and roles of distinct basic and clinical sciences, yet a clear discomfort with the practical segregation of the two in curriculum design and delivery. For example: "*...we're still suffering from that psychological dichotomy [between basic and clinical], as I call it. I think it's time to take a look at the way the curricula are laid out and say, 'How do we deal with this?'"* As increased focus is placed on formal training in newer competency areas (usually related to the social sciences, for example communication skills or conflict resolution), the fundamental importance of basic sciences, to some, risks being undervalued. At risk is one's ability to fully engage in optimal diagnostic reasoning and patient management: *... without a solid underpinning of, for example, pathophysiology, I don't know how you could really interpret clinical signs, symptomology, the basics of pharmacotherapy ... I mean you've just got to understand that stuff",* or *: "I'm impressed by the fact that physicians do it well because they really understand the nature of the biological beast ... my concern is that that's getting lost in the shuffle."*. Furthermore, a sound basic science knowledge was seen as key to remaining current in one's practice, given that advances in practice will most likely arise from advances in basic sciences research. An individual practitioner's ability to rapidly interpret

new research findings in the context of their practice was noted to require a sound understanding of the basic science foundations underpinning the discovery. Any controversy about the role of basic science in medical school education, or the acknowledgement that it is a topic of concern, arose primarily among those intimate with the profession. Participants from outside of medicine largely failed to identify or appreciate the issue.

The traditional stark dichotomy between the sciences also came into question:"*What constitutes a basic science*?" Rather than basic versus clinical sciences defined by content areas (physiology versus communication skills, for example), what were traditionally seen as the social sciences now also have their own foundational 'basic' versus 'applied' implications. In one identified example, the clinical practicalities of influencing positive health behavior change (in a community-based practice remain rooted in the same 'basic sciences' of prevention, population health, epidemiology, and behavioural and social science as they would be in an academic health sciences centre., . Sound understanding of the foundations of informatics and knowledge translation was perceived to be emerging as a basis for good medical and educational practice. This notion of expanded basic sciences was strongly supported by a group of Canadian medical educators who convened in 1999 to discuss the role of basic science in medical education and was echoed in other parts of our data set (interviews and focus groups). (Mandin 2000) A new dichotomy, defined not by content area (biology vs. anatomy, vs. sociology, etc) but based instead on the utility of the information, had clear resonance across data sources: foundational (or theoretical) science vs. applied science.

Basic science is critical to physician identity

Despite the popularity of symposia, innovations and academic debates around the role of basic sciences in medical education, there was remarkably little disagreement in our data set that a sound basic science knowledge is critical to future medical practice. Specifically, it was perceived to form the basis for the understanding of diagnostic decision-making, treatment deliberations and monitoring and integration of future research into practice. Furthermore, the basic science genesis of medical thinking was perceived to serve as a conceptual and foundational distinction between the western biomedical model and most other forms of clinical practice. From our analysis, it became clear that in the Canadian context, the medical profession is expected to lead discovery and advance health sciences.

Integrating the two sciences

Few reservations arose about the need for new models of education or about the need to further integrate the 2 sciences. The support for new competency-based models such as the seven CanMEDS Roles, for example, clearly indicates a perception that physicians must have facility with many more content areas than were previously emphasized in Flexner's era. (RCPSC 2011) If training is to remain the same length or fail to benefit from advances in efficiency, this in effect speaks to a reduction in traditional basic sciences focus in exchange for other areas of emphasis. This tension between increased spectrum of competencies and a time-limited **curriculum clearly** arose: "*... the basic sciences can get squeezed, talked down or talked over.*" Even those who agree on a strong basic sciences foundation envisioned an effective integrated model as long as basic science fundamentals explicitly and deliberately remain: *"You don't have to spend a whole year in the anatomy lab or in biochemistry necessarily like in the good old days. We use systems learning and [basic sciences] can be integrated; I'm not saying that*

*everybody must spend this prescribed time. What I'm saying is that curriculum planners must ensure basic principles are incorporated into problem-based learning or another way."*The advent of new educational technology, most notably simulation, was seen as a focal point in the shift of debate from one of simply when students know enough to be 'allowed' to interact meaningfully with patients. Alternatives now exist that allow students to conceptualize new knowledge, establish relevance, and focus on the application of knowledge in between the classroom and the real bedside.

Finally, while these trends facilitate integration of the sciences, practical and political considerations come to bear as implications of these trends. Transitions from one model to the other often require the realignment of resources and expectations related to the professoriate and clinical faculty. For example, the traditional sequential model facilitated non-physicians' teaching of basic sciences in keeping with a university departmental model. Newer models bring simmering debates to the forefront since basic scientists often feel that medical practitioners are not well equipped to teach to an appropriate depth in basic sciences or appropriately incorporate new advances and nuance into their teaching. Physicians on the other hand, are more able to appreciate the clinical applicability of basic science content and thus feel more able to foster learning in an integrated model.

Discussion

Little dissent arose around the importance of learning basic sciences in medical school, but arguments around the amount, conceptualization and delivery of this education was far from consistent in our data set. Discussions of the role of basic sciences question the need for all

graduating medical students to have the same degree of basic sciences knowledge. The overarching principles of the AAMC/HHMI report allude to this: “Application of scientific knowledge in medicine requires attention both to the patient as an individual and in a social context”, and “ The effective practice of medicine recognizes that the biology of individual patients is complex and variable and is influenced by genetic, social and environmental factors”. (Prideaux 2001) However, as Norman (2000) discusses, all clinicians at times require some basic science grounding but different specialties require it to different degrees. Furthermore, those destined for careers in research require more exposure than those destined for purely clinical practice yet preparation for both career options has been seen as appropriate for the ‘undifferentiated’ medical student. Thus, a cohort of researchers must arise from those in the training system and interest in this career fed through early and meaningful exposure to the basic sciences. While there is little debate about the need for the profession to balance clinical care provision with research, the physician as researcher may become more essential to the professional identity in the future. The traditional unique role of the physician is being challenged. For example, the competencies of other health professionals are evolving to encompass some activities formerly held to be unique to physicians, and information technology is shifting the intellectual role of the physician from that of primarily a knowledge repository to that of a knowledge integrator or broker. The idea of physician as knowledge generator and academic problem solver thus become more important as a means to achieve the leadership expected of the profession. This tension is particularly important in the Canadian context where undergraduate medical training is heavily subsidized from public funds and residencies are entirely publically funded. As a provincial (rather than national) mandate, Ministries hold faculties accountable primarily for producing a stable supply of competent providers for the

provincial population at the minimum cost and often at the expense of prioritizing specialized training in research or leadership (which is often seen as a national resource). In recognition of the need for increased flexibility in preparatory training, a number of North American schools now provide discrete opportunities for basic science research (in addition to or in place of basic science teaching) for interested students (AAMC 2011). Duke Medical School has included with its longitudinal clinical experience a ten-month in-depth basic science research project. (http://medschool.duke.edu/module/50m_curriculum/index.php?id=3 accessed November 2012). The Cleveland Clinic Lerner School of Medicine provides a five-year curriculum focusing on basic science in the first two years while including ongoing clinical exposure and then allows students to diversify based on their relative clinical and research interests. Harvard Medical School uses a technology-enabled approach, bringing basic sciences alive with clinical context through simulation and web-based resources in the classroom. A number of recent publications address the integration of basic sciences into curricula using new techniques and technology. (Takkunen et al. 2011, Chen & Pawlina 2009, Dubois & Franson 2009)

If practice reflects a shift in predominant thinking, then arguments for integrated curricula have been compelling since such designs, especially the horizontal model, have become more popular in Europe, North and South America and Australia (Dahle et al. 2002). Indeed, over 50% of Canadian, 88% of Australian and 50% of UK medical schools had horizontal integration of their undergraduate medical curricula by 1999 (Elliott 1999). One notable example of a full spiral curriculum is found at the University of Dundee. Characterized by repetitive exposure to theme-based topics at greater and greater levels of sophistication and building new knowledge upon old, this model is proposed to incorporate the best of previous models, revisiting both basic and

clinical sciences as necessary to encourage problem-solving and establish context for ongoing learning. (Davis & Harden 2003). The literature on effective curricular integration has evolved to the degree that new review or synthesis articles are starting to appear, such as 2 published recently in Medical Teacher. (Dahle et al. 2002, Davis & Harden 2003) Furthermore, the needs of teachers mandated by these transitions have also recently been the focus of literature reports; teachers can and must be adequately supported in their efforts to adapt to new curricular models. (Gregory et al. 2009)

While there has thus been a considerable shift away from Flexner's '2+2' model and numerous innovative approaches to integrating the two 'sciences' to help future physicians meet societal needs, there remains little definitive evidence to indicate the best model for medical education. Clear support of one model over another would require a firm consensus on an appropriate outcome measure and a rigourous comparative design. While some attempts to do this have been made and have shown small advantages for problem-based curricula over traditional curricula on issues of lifelong learning, clinical skills and ability to address psychosocial issues, definitive evidence encompassing a breadth of clinical practice indicators has yet to appear. (Vernon & Blake 1993). It is curious that the 'sciences' debate arose only within the professions and not from lay or naïve contributors to our data set. The reason for this relative dearth of attention is a matter of conjecture. It is likely that the teaching of basic sciences is not seen as a contentious issue to those outside of the medical education environment either because it is assumed to be a fundamental part of medical education about which there is little to debate or the distinction between basic and clinical sciences is not appreciated in the same manner as it is among those who teach and learn in medical schools.

External realities, such as accreditation requirements and certification processes, influence curriculum design. Change is afoot here, too. For example, in the United States, the USMLE Step 1 basic science examination has been undertaken by candidates at the end of second year. This has tended to perpetuate the divide between preclinical (basic sciences) and clinical curricula. Recently endorsed changes will see two assessment points (at the interface between undergraduate and graduate medical education (supervised practice) and at the beginning of independent (unsupervised) practice) and the adoption of a general competencies schema for the design and scoring of the examination consistent with national standards such as the ACGME general competencies. Implementation of these recommendations would create a single year 4 competency-based examination in which basic science is truly integrated with clinical context. In theory this will give schools more flexibility in how they structure curricula and facilitate longitudinal integration.

The final AFMC Collective Vision document includes as a key recommendation, "Build on the scientific basis of Medicine." (AFMC 2009) The predominant sentiment of this recommendation is in alignment with the sources of data summarized in this paper, including the critical role basic sciences play in forming the physician identity, the need to expand the notion of basic science to include the fundamentals of other disciplines, and the need to skillfully integrate the learning of all sciences throughout the curriculum. Elaboration of this key recommendation states that "both human and biological sciences must be learned in relevant and immediate clinical contexts throughout the MD education experience." The document further adeptly articulates that integrated curricula hold promise to enhance the learning of *both* clinical and basic sciences

compared to a sequential model: "While recognizing that it is important to underscore the scientific basis of medicine, this recommendation recognizes the value of both basic science and clinical instruction. These two complementary domains must be increasingly integrated so that students think about clinical applications as they learn basic sciences and about scientific principles as they learn clinical skills." The task, then, is for curriculum planners to address the following issues: a) decide how best to structure their education model with regards to type of future practice **(e.g.** when to 'stream' students based on research interest or envisioned future specialty), b) match the educational objectives of each group to their basic science needs including newer disciplines such as social sciences, c) make conscious links between basic science knowledge and future utility recognizing both the applied and foundational nature of the former and d) make innovative use of traditional clinical education experiences and new technologies to achieve strong cognitive integration of all relevant knowledge for future practice.

Conclusions

For today's societal needs, Flexner's '3+1' sequential model of basic and clinical instruction was weighted too much towards basic science at the expense of other, less traditional content areas such as communication skills and social determinants of disease. In recognition of these expanded competency areas, more current discourse has shifted the dichotomy debate from basic/clinical to fundamental/applied. There has been a widespread adoption of integrated curricula around the world, indicating broad face validity for the concept of contemporaneous rather than sequential learning of the sciences. Changes in curricula content and design will be expected to occur in alignment with changes in our understanding of how students learn and clarity around the role of the physician. Teachers are being challenged to bring teaching of the

fundamentals into their clinical practice in all content domains. They will be expected to explicitly teach material they themselves were never taught but learned implicitly. New methods of integrated teaching using simulation **have** enabled safer education but challenged teachers to change how they plan curriculum and make clinical teaching relevant to the lessons taught using these newer methods. It is likely, given the difficulty in establishing firm outcome measures and logistically planning comparative studies of educational models, that incremental change is to be the norm in the future of medical education. The balance of clinical and basic sciences, and their integration in a manner that best serves the student of medicine are sure to be the focus of much innovation yet to come.

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References

AAMC-HHMI Committee Report. Scientific foundations for future physicians. 2009. Association of American Medical Colleges. Washington USA.

Association of American Medical Colleges. [Cited 2008 March] Curriculum Management and Information Tool. Available from http://aamc.org/meded/curric/.

Association of Faculties of Medicine of Canada. [cited 30 November 2011] Steering Committee: Who is Involved: FMEC. 2010; Available from: http://www.afmc.ca/future-of-medical-education-in-canada/medical-doctor-project/who-is-involved-committee.php

Association of Faculties of Medicine of Canada. 2009. The Future of Medical Education in Canada: A Collective Vision for MD Education. Ottawa: AFMC,

Barrows HS, Tamblyn RM. 1980. Problem-based learning. New York: Springer Press.

Cooke M, Irby DM, Sullivan W, Ludmerer KM. 2006. American medical education 100 years after the Flexner report. N Engl J Med 355 (13):1339–44.

Chen LP. Pawlina W. 2009. Restructuring a basic science course for core competencies: an example from anatomy teaching. Med Teach 31(9):855-61.

Dahle LO, Brynhildsen J, Behrbohm Fallsberg M, et al. 2002. Pros and cons of vertical integration between clinical medicine and basic science within a problem-based undergraduate medical curriculum: examples and experiences from Linköping, Sweden. Med Teach. 24(3): 280-285.

Davis MH, Harden RM. 2003. Planning and implementing an undergraduate medical curriculum: the lesions learned. Med Teach 25(6): 596-608.

Dubois EA. Franson KL. 2009. Key steps for integrating a basic science throughout a medical school curriculum using an e-learning approach. Med Teach 31(9):822-8.

Elliott MK. 1999. Are we going in the right direction? A survey of the undergraduate medical education in Canada, Australia and the United Kingdom from a general practice perspective. Med Teach 21(1): 53-60.

Flexner A. 1910. Medical Education in the United States and Canada (bulletin no.4). New York: The Carnegie Foundation for the Advancement of Teaching.

Flexner A. 1925. Medical Education: A Comparative Study. New York, NY: MacMillan.

Gatenby PA. Martin R. 2009. Development of basic medical sciences in a new medical school with an integrated curriculum: the ANU experience. Med Teach 31(9):829-33.

Ginexi EM. 2006. What's next for translation research? Evaluation and the Health Professions 29(3):334-347.

Gregory JK. Lachman N. Camp CL. Dieter PE. 2009. A Faculty Development Program can result in an improvement of the quality and output in medical education, basic sciences and clinical research and patient care. Med Teach 31(7):655-9.

Glew RH. 2003. The problem with problem-based medical education. Promises not kept. Biochem and Mol Educ 31(1): 52-56.

Hodges BD, Albert M, Arweiler D, Akseer S, Bandiera G, Byrne N, Charlin B, Karazivan P, Kuper A, Maniate J, Millette B, Noyeau E, Parker S, Reeves S. 2011. The Future of Medical Education: A Canadian Environmental Scan. Medical Education 45(1):95-106.

Irby DM, Wilkerson LA. 2003. Educational innovations in academic medicine and environmental trends. J. Gen. Intern. Med. 18(5):370-376.

Kirschner PA, Sweller G, Clark RE. 2006. Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educ Psych. 41(2): 75-86.

Laidlaw A. Hart J. 2011.Communication skills: an essential component of medical curricula. Part I: Assessment of clinical communication: AMEE Guide No. 51. Med Teach 33(1):6-8.

Malik AS. Malik RH. 2011. Twelve tips for developing an integrated curriculum. Med Teach 33(2):99-104.

Mandin H. 2000. Foundation science for medicine in the 21st Century. Clin Invest Med 23(1): 1-109.

Norman SR, Schmidt GR. 1992. The psychological basis of problem-based learning. Acad Med 67: 557-565.

Norman GR. 2000. The essential role of basic science in medical education: the perspective from psychology. Clin Invest Med 23(1): 47-51.

Patel V, Goren SJ, Scott HM. 1988. Biomedical knowledge in explanations of clinical problems by medical students. Med Educ 22: 398-406.

Pawlina W. 2009.Basic sciences in medical education: why? How? When? Where? Medical Teacher. 31(9):787-9.

Prideaux D. 2001. Country report: Australia. Med Educ 35: 495-504.

Royal College of Physicians and Surgeons of Canada website, Resources. http://www.royalcollege.ca/public/canmeds/resources/publications/#CanMEDS_Physician_Competency. Accessed December 2011.

Shield RR. Tong I. Tomas M. Besdine RW. 2011. Teaching communication and compassionate care skills: an innovative curriculum for pre-clerkship medical students. Med Teach 33(8):e408-16.

Takkunen M. Turpeinen H. Viisanen H. Wigren HK. Aarnio M. Pitkaniemi J. 2011. Introduction of real patients into problem-based learning in preclinical first-year anatomy curriculum. Medical Teacher. 33(10):854-6.

Vernon DT, Blake RL 1993. Does Problem-Based Learning Work? A meta-analysis of evaluative research. Acad Med 68(7):550-563.

Woods NN, Brooks LR, Norman GR. 2005. The value of basic science in clinical diagnosis: creating coherence among signs and symptoms. Med Edu 39: 107-112.