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No content without context: Integrating basic, clinical, and social sciences in a pre-clerkship curriculum

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Abstract

Background: The basic science curricula in medical schools ultimately succeed or fail at the bedside when students must draw on their pre-clerkship experiences as they learn to form nuanced clinical decisions. Given this expectation, learning context becomes as decisive as content in determining students' recall and application.
Aims: Using the pre-clerkship medical curriculum at the University of California, Los Angeles, as an example, we illustrate how traditional biomedical sciences can be integrated with clinical sciences in a comprehensive foundational curriculum following curricular design features and teaching methods based on learning principles from cognitive psychology and education.
Methods: Multiple planning teams of faculty and students collaborated in the design of the Human Biology and Disease (HB&D) curriculum. Broad participation, careful selection of course chairs, the assistance of educational consultants, ongoing oversight structures, and faculty development were used to develop and sustain the curriculum.
Results: The resulting HB&D curriculum features an interdisciplinary spiral block structure including interactive lecture formats, integrative formative and summative examinations, self- and peer-taught laboratories, and problem-based learning with innovative variations.
Conclusion: Our fully integrated, spiral, pre-clerkship curriculum built on repeating interdisciplinary blocks and longitudinal threads has yielded encouraging results as well as some specific innovations that other schools or individual teachers may find valuable to adapt for use in their own settings.

Background

Though taught primarily in lecture halls and laboratories, medical school basic science curricula ultimately succeed or fail at the bedside when students need to draw upon their entire fund of knowledge as they learn to form nuanced clinical decisions. In this setting, learning context becomes as decisive as content in determining whether fundamental scientific principles are available for recall and incorporation into illness scripts, schema, and other sophisticated knowledge constructs (Koens et al. 2005; Bowen 2006; Bordage 2007; Schmidt et al. 2007).

Traditional pre-clerkship curricula, with each science discipline offering its content from within a departmental silo, frequently fail learners as they advance to the clinical years. Information presented without robust cross-links and ties to clinical applications, and tested in isolation from related subject matter, has proven difficult for students to recall after the transition to clinical clerkships (Prince et al. 2000; Blake et al. 2000; Hoffman et al. 2006).

Since the time of Flexner, the basic science medical school curriculum has largely consisted of discrete courses controlled by individual departments (Cooke et al. 2006). Such curricula have largely included an initial phase focused on normal structure and function followed by a pathophysiology phase, sometimes organized around organ systems or taught during core clinical rotations.

Practice points

- The prevailing trend in basic science curriculum around the world is toward integration, both horizontally among disciplines and vertically between basic and clinical sciences.
- Research findings from cognitive psychology and education can be helpful in designing curricular structures and teaching methods to stimulate deep learning, enhance students' abilities to apply basic science to patient care, and promote habits of personally driven learning.
- Variations in PBL can provide students with practice in specific skills related to clinical reasoning and evidence-based medicine.

Dissatisfaction with this curricular model has included students' complaints about lack of relevance and faculty members' concerns about students' failure to recall relevant basic science knowledge during their clinical education. Medical students have viewed the basic science curriculum

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as a hurdle to be overcome in order to earn the right to step onto the hospital wards. And clinical teachers have complained that when students arrive on the clinical rotations, they have no intellectual curiosity, having spent the first phase of medical school memorizing unrelated facts rather than learning to think like a clinician.

In response to these complaints, basic science educators have added guest lectures by clinical faculty members, used brief case vignettes in traditional laboratories, reduced the time spent in traditional laboratory instruction, reorganized scientific content around organ systems, developed more innovative lecture techniques, and added computer simulations and self-study modules (Small & Suter 2002; Amin & Eng 2003). In 1969, McMaster Medical School challenged the assumption that students could only learn basic science by listening to the experts; faculty replaced the traditional lecture and laboratory basic science curriculum with problem-based learning (PBL) in which small groups of students working with cases and problems under the guidance of a faculty tutor could be trusted to identify essential learning questions and educate themselves through independent and peer teaching (Barrows & Tamblyn 1980). Few medical schools in North America were willing to adopt this curricular model until Harvard Medical School created a hybrid curriculum in 1985 that combined PBL with limited lectures and laboratories in order to help students develop a flexible, integrated knowledge base (Moore 1994). Using a block structure rather than concurrent courses to promote integration and encouraging partnerships between basic science and clinical faculty members in designing these blocks, Harvard demonstrated that students could learn basic science in the context of clinical medicine and humanistic care while maintaining sufficient content mastery to pass the national licensing examination with no decrement in basic science knowledge (Moore et al. 1994). The prevailing trend in basic science curriculum change around the world is now towards integration, both horizontally among disciplines and vertically between basic and clinical sciences, often including PBL as an integrative function (Harden et al. 1984; Irby & Wilkerson 2003; Cooke et al. 2006; Woods 2007).

Recognizing the limitations of its own traditional, departmentally based curriculum, the medical school at the University of California, Los Angeles (David Geffen School of Medicine at UCLA) challenged its basic science faculty members to sit down with their clinician colleagues and craft a new, fully integrated pre-clerkship curriculum that would present "no content without context". The result was the launch in 2003 of "Human Biology and Disease" (HB&D). An initial Structure Task Force reviewed the literature and interviewed colleagues from medical schools across North America with innovative basic science curricular models. The Task Force recommended three principles to guide the work of subsequent curriculum design teams:

(1) The integration of basic, clinical, and social sciences is essential to clinical practice and research.
(2) Application of knowledge requires both mastery of facts and deep understanding acquired through deliberate practice and the use of multi-modal learning methods.
(3) The attitudes and skills essential for a lifetime of learning are central to professional practice and research.

Aims

In this article, we use the pre-clerkship curriculum at UCLA to illustrate how traditional biomedical sciences can be integrated with social and clinical sciences. In addition, we describe specific curricular design features and teaching methods built on learning principles derived from cognitive psychology and intended to stimulate deep learning, enhance students' abilities to apply basic science knowledge to patient care, and promote habits of personally driven learning.

Methods

Over 250 faculty members and students participated in one or more planning teams to produce eight, and subsequently nine, integrated block courses. Block and thread chairs were selected in a collaborative discussion among the heads of the curriculum committee, the curricular dean, and the department chairs. Each department chair was asked by the Dean to provide a number of faculty members who could serve as PBL tutors in relation to the number of full-time faculty positions funded by the University for that department.

Faculty members from the Center for Educational Development and Research (ED&R) teamed up with each pair of block chairs to provide consultation on aspects of course design, assessment, and faculty development. PBL tutor training workshops were scheduled throughout the year and have continued into the present so that new tutors can learn about PBL facilitation by participating in and observing a case discussion. Each block schedules weekly case preview sessions that include a time for the discussion of the various skills and responsibilities expected of PBL tutors plus troubleshooting of unexpected issues. New tutors are observed and provided feedback by the educational consultants.

The curriculum committee established a new subcommittee composed of the HB&D block chairs and thread chairs that meets monthly for peer review of block plans and outcomes as well as collaborative discussion and resolution of ongoing issues in curricular implementation, e.g., use of video to enrich PBL cases, podcasting of lectures, and absence policy. Policy recommendations are referred to the curriculum committee for consideration. These infrastructure activities continue to be essential to the success of the HB&D curriculum.

Results. The human biology and disease curriculum

Curricular structure

HB&D is an integrated foundational curriculum that unfolds in nine sequential block courses over 2 years, each block traversed by five, discipline-based threads, as illustrated schematically in Figure 1. Block courses consist of either 8 or 5 weeks of classroom and clinical study followed by 3 days for

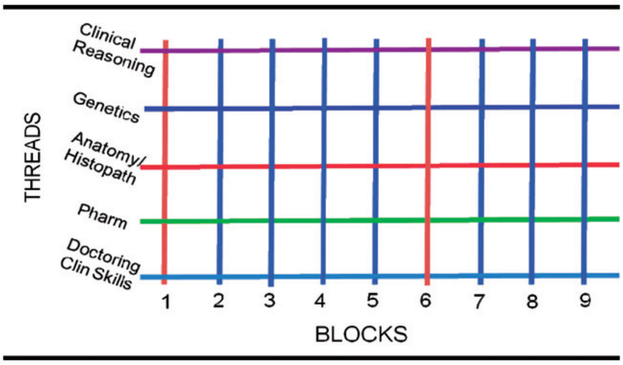

Figure 1. Integration of discipline-based threads with system-based blocks.

an integrative examination and a 4-day break. An introductory week initiates the students into HB&D, and a week of comprehensive testing occurs at the end of the 19-month period. The distribution of block courses over the 2 years is illustrated in Figure 2. Each year begins with a "Foundation" block that covers basic processes that underlie the normal and pathological functioning of all tissues and organs. The remaining blocks are organized around organ systems sharing common features, e.g., Cardiac, Renal, and Respiratory Medicine. All blocks except Musculoskeletal Medicine repeat across the 19-month period, making the curriculum an ascending spiral in which content is purposively repeated at a higher level of complexity (cf "spiral curriculum" in Bruner 1960). Design teams working on the same block for its first and second iterations began by agreeing to an emphasis on selected pathophysiologic concepts in each iteration with the second, featuring more complex, multi-system pathologies. Normal and abnormal processes of health and disease are addressed concurrently throughout.

Each block is co-chaired by a basic scientist and a clinician who are responsible for the content and context of the knowledge, skills, and attitudes addressed during the block, as opposed to the more traditional "subletting" of disciplines. Monthly meetings of all block chairs and thread chairs help to coordinate distribution of material among the blocks, continuity, and purposeful repetition of material between the first and second iterations, dissemination of innovations, and discussion of innovations and outcomes.

Each of the blocks follows a similar weekly structure:

- PBL tutorials at the beginning and end of each week
- A maximum of 10 h a week of lectures
- A weekly clinical session of 3 to 4 h
- A maximum of 24 h a week of total contact time
- A formative assessment at the end of each week.

Typical HB&D week

Figure 3 illustrates the layout of a typical week. Specific examples from this week, which occurs toward the end of Foundations of Medicine I, illustrate how we integrate the basic biomedical, social, and clinical sciences.

Lectures. The content of this week focuses on adaptive immunity. Although lectures focus primarily on the basic science underlying this process, most include clinical applications and some public health, social, or ethical issues. For example, "immunodeficiency and the concept of vaccination" discusses herd immunity and introduces the problem created by families who eschew childhood vaccinations; that lecture also uses the development of the rotavirus vaccine to discuss the mix of scientific and ethical issues involved in testing vaccines on disadvantaged populations, in this case in Third World countries. The week concludes with a lecture that applies the basic science material to a clinical condition (HIV) along with a session, "clinical applications", in which several clinical vignettes are presented that require students to call upon their understanding of adaptive immunity to answer questions, using an audience response system (ARS), about underlying processes.

Problem-based learning. The week begins and ends with a PBL tutorial, here the case of an African–American man troubled by a persistent cough and night sweats. On Monday, students encounter the actual patient through a video interview then consider narrative descriptions of patient data and the patient's experience with the health care system, before identifying learning issues for independent research during the week. On Friday, students return to PBL to discuss the results of their self-study as it applies to the case thus far and to additional unfolding segments using both paper and video. As part of PBL, students read a journal article, which in this week investigates the cellular pathways through which vitamin D mediates antimicrobial responses and relates the results to why people with dark skin might be more susceptible to TB. One student leads a critical appraisal of the article in a PBL variation that we call "journal club".

Doctoring/clinical skills. Working in groups of eight, students interview a standardized patient (SP) portraying a homeless mother with two small children who is coming to a public clinic that serves indigent and uninsured patients to seek medical care. In preparation for this session, the students have been assigned readings on the relationship between poverty and illness and information on services available for the indigent. Through their interview with the SP, students explore the family's health, economic, social, and emotional environment, vaccination history, and TB risk, then counsel for screening and immunization.

Laboratories. In a histopathology lab, students use team-based learning (Michaelsen et al. 2007) to demonstrate their mastery of self-study modules before working in teams on clinical cases illustrated with pathology slides in which they must discriminate among infection, inflammation, and neoplasia, which have been covered in previous weeks. In an immunization lab, students learn about vaccination schedules and apply their knowledge to a series of clinical vignettes presented via a Jeopardy-like game. In addition, they practice placing a tuberculin skin test on one another (using saline) and interpreting levels of induration on simulated forearms.

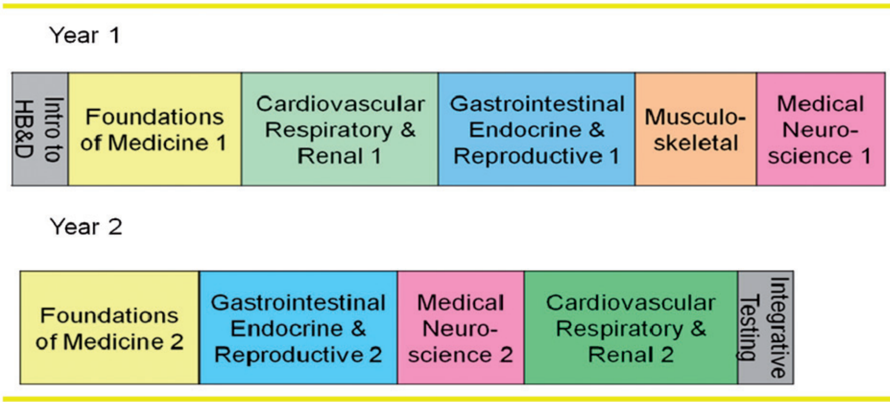

Figure 2. Organization of Human Biology and Disease blocks over the first two years of the pre-clerkship curriculum at the medical school at UCLA. Blocks are integrated around the indicated systems; the Foundations blocks target the immune system, integument and blood. With the exception of the 5-week Musculoskeletal block, all blocks repeat in the second year.

	Monday	Tuesday	Wednesday	Thursday	Friday
8–10 AM	*PBL:* Mr. Love's Cough Pt1				*PBL:* Mr. Love's Cough Pt2 & Journal Club
10 AM	Anatomy & Development of the Immune System	Antigens & the T cell Molecules that Recognize Them	A Linear Response to Two Pathogens	Titrating Non-self & Self Recognition: Hypersensitivity & Auto-immunity	HIV Infection & Failure of Adaptive Immunity
11 AM	Antigens & the B cell Molecules that Recognize Them	Major Histo-compatibility Molecules & Antigen Processing	IG *vs* T-cell Mediated Damage	Immuno-deficiency & the Concept of Vaccination	Clinical Applications
12 PM					
1 PM		Immunization Lab: Immunization Schedules & TST practice (2.5 h) OR Histopathology: Chronic & Granulomatous Inflammation (2.5 h) OR Doctoring/Clinical Skills: Intervie wing an indigent family that has come to a free clinic for health care (3 h)			Formative Assessment (Friday PM to Monday AM)

Figure 3. Example of weekly organization under the HB&D curriculum. This schedule is from Week 7 of Block 1 (Foundations of Medicine 1) of the first-year curriculum. On Tuesday through Thursday, students rotate through afternoon lab/doctoring activities with 1/3 of the class/day in each activity.

Incorporation of learning principles into curricular design and teaching

Development of the curriculum and teaching strategies has been grounded in principles emanating from research in cognitive psychology and education. These principles, which we refer to as AIDERS, are enumerated in Figure 4. The teaching strategies and components described below incorporate these principles, but they also underlie features of the curriculum described above. A block structure enhances attention and focus by reducing the need for students to simultaneously study parallel courses and allows structured integration of and generalization to multiple contexts. Fewer lecture hours per week, along with less total contact time, enhance attention and provide unstructured time for processing knowledge. Integrating the basic, social and clinical sciences provides for contextual learning, thereby increasing deep understanding. Small group experiences in PBL and doctoring expose students to multiple perspectives and opinions during the discussion of complex problems. Planned and deliberately spaced repetition promotes retention of learning and development of skills (Thios & D'Agostino 1976; Shebilske et al. 1999; Bahrick & Hall 2005).

Within this new curriculum, we have implemented a number of teaching methods to promote learning, increase retention, and enhance students' ability to apply what they are learning. The following methods can be of use to the individual teacher within the context of many different curricular models.

Lectures for active learning

In addition to limiting the number of lecture hours each week, we have incorporated several features that increase attention and active learning during lectures. The first is to provide an organizational framework that helps students pay attention to key points and assimilate details during the lecture. We provide lecture outlines, reading assignments, and PowerPoint files ahead of time and encourage the students to preview these prior to the lecture. Hierarchical-style notes have been shown to be a more effective learning tool than either detailed notes or no notes at all (Morgan et al. 1988; Kiewra et al. 1995).

We also web/podcast all lectures after their delivery. The program used for web/podcasting allows students to jump to individual slides to hear what was said at specific points in the presentation, letting students easily review, retrieve, or correct any missed material. In addition, web/podcasts allow students to control the pace of lectures, interrupting them as desired to think about, or look up resources relevant to the information being presented.

Although we have no data to indicate the contributions of these factors, attendance rates at lectures are higher and significantly more sustained throughout the first two years than in the previous traditional curriculum. This observation is particularly interesting considering that students now have access to web/podcasts of the lectures and all lecture materials online.

Formative assessments and feedback

Using an ARS allows instructors to add learning and formative assessment during large-group classroom presentations. Students participate by electronically submitting answers to questions provided during the presentation (e.g., on a PowerPoint slide), which are then collated and displayed. Questions can require students to retrieve relevant prior knowledge, apply material to new contexts, or test their understanding of new material while receiving immediate feedback by comparing themselves to the class result. Embedded questions also draw students' attention to key ideas. We issue ARS keypads to students for use throughout their medical education. ARS questions can be used to help the instructor identify levels of prior knowledge or preconceived ideas represented in a class and thus better target the subsequent presentation. Although possible, we do not monitor individuals' ARS responses during lectures.

Weekly, online, formative assessments (quizzes) provide another method of deliberate practice and regular feedback to students. Using a web-based course management system, we provide a 10–20 question quiz at the end of each week which

"AIDERS" for instructional planning

- **A**ttention: We can only learn those things to which we pay attention (Tyler et al. 1979; Iidaka et al. 2000).
- **I**nterpretation: We interpret new knowledge through associations with pre-existing knowledge, experience-driven schemas or cognitive structures (Smith & Vela 2001).
- **D**eep understanding: Deep understanding requires opportunities to generalize specific concepts or problems using a variety of modalities and/or contexts (Bordage 1994).
- **E**xposition: Deliberate practice requires focused rehearsal, generation rather than just recognition activities, and retrieval practice (Smith & Vela 2001).
- **R**einforcement/restructuring: Feedback serves to strengthen or restructure an individual's interpretation of experience (Hattie & Timperley 2007).
- **S**ocial construction: Learning is socially constructed with exposure to multiple perspectives associated with the development of more complex reasoning processes and greater acceptance of differences (Watson et al. 1998; Antonio et al. 2004).

Figure 4. A mnemonic for principles of cognition and learning. In developing the curriculum and the teaching methods, we attempted to optimize several components of effective learning demonstrated through research in cognitive psychology, education, and the neurosciences as having critical influences on learning (de Winstanley & Bjork 2002 for a review; Donovan et al. 1999; Regehr & Norman 1994).

students are required to take over the weekend as a self-assessment exercise. Quiz scores do not count toward the course grade but can be used by block chairs as the basis for academic counseling. Questions include material from all facets of the previous week: lectures, labs, clinical exercises, and PBL cases. The questions and format of these assessments model those of the summative assessments used at the end of each block, thereby informing students of the level of understanding expected of them (Krasne et al. 2006). Student response to weekly formative assessment has been extremely positive with 89% of first-year students at the end of Block 1 reporting that their personal performance results on the weekly formative assessments led them to "study with a different emphasis" (Krasne & Relan 2005).

Integrative summative examinations

Summative exams are administered over a 3-day period at the end of each HB&D block and include an online multiple-choice/short-answer examination, a clinical skills performance assessment, and an anatomy/radiology practical exercise. One block also includes an un-timed, open-book component. As with weekly assessments, material from all components of the block is included in the online exam. In order to pass the block, students must pass the online, practical, and clinical examinations and receive passing ratings from their small-group facilitators in the PBL, doctoring and clinical skills groups. Examination questions are key-worded by discipline so that performance feedback can be provided to students without returning the exam itself, allowing the faculty members to study the psychometric performance of the items and make continual improvements to better target the examination to a designated passing standard.

Self- and peer-teaching laboratory sessions

Innovative laboratories have emerged as block and thread chairs have worked to promote students' active engagement with the material through self- and peer-teaching and application of basic science content to the understanding and resolution of meaningful clinical problems. Team-based learning (Michaelsen et al. 2007) serves as the instructional format for a series of laboratories combining histology and pathology. Team-based learning requires individual mastery of factual material prior to class time which can then be spent on the application of that material to complex problems. In preparation for histopathology laboratories, students complete an online self-study module on basic histology constructed using an interactive software program. There are no normal histology lectures in the HB&D curriculum. On arriving at the lab, students join a team of 6–8 students. Students begin by answering a 10-item individual readiness assurance test (IRAT). The instructor then reviews this formative assessment with the students (or uses a group readiness assurance test) to correct common mistakes. This 30-minute warm-up exercise ends the focus on normal histology, and student teams turn their attention to the discussion of pathology cases using online slides that can be manipulated as if they were under a microscope, and wet specimen from autopsies. The two laboratory instructors, one cell biologist and one pathologist, circulate to answer questions and prod students for deeper understanding. During the final 20-minute segment of the laboratory, the two instructors provide a synthesis of major concepts with particular attention to the misunderstandings they have encountered in listening to the teams at work.

Anatomy instruction also occurs as a thread across the first five blocks of HB&D using a variation of the same team-based learning format. There are few formal lectures on normal anatomy in the weekly series. Instead, students are required to come to anatomy lab having completed computer-based self-instructional modules. Laboratory time is spent with teams of students working with prosections (prepared by post-year-1 students) and radiology images on computer monitors at each dissection table with students' applying basic anatomical detail to the understanding of clinical vignettes. In these laboratories, students can compare normal and diseased tissues in both intact and histological preparations using fixed and fresh tissues. Laboratory instructors include a radiologist and surgeon in addition to several anatomy instructors. Limited dissection occurs during the Musculoskeletal Medicine block.

Simulation-based laboratories also provide an opportunity for the application of basic concepts. For example, during the Cardiovascular, Renal, and Respiratory 1 block, students work with a full-body computerized simulator to explore basic cardiac function, an exercise carried out in our previous curriculum in an animal laboratory. Not only do students use this simulator to measure variables of cardiac output (e.g., rates, pressures, and volumes) during normal and simulated disease states, but the simulator provides immediate feedback as students adjust the variables and mechanisms used by the body and/or by physicians (e.g., increased vagal input, increased fluids, defibrillation) to bring the body's circulatory system back to normal ranges. Other simulation laboratories explore the mechanisms of shock and cardiac failure and provide practice for practical skills, such as venipuncture, pelvic examination, and suturing. Simulation exercises provide students with the opportunity to make decisions, both individually and as a team, and to experience first-hand the results of those decisions.

PBL innovations

While PBL remains a learner-driven activity centered on students' discussions of clinical cases, we have developed a series of innovations to stimulate learning of specific skills and attitudes. In addition to its traditional use in helping students integrate the biomedical and clinical sciences, PBL can provide a venue for students to learn oral and written communication skills, clinical reasoning and evidence-based medicine, concepts of public health, ethics, and health policy, as well as to develop patient-centered care attitudes and clinical skills. This expanded role for PBL can be accomplished through purposeful case design and the use of specified student roles.

Narrative case design. PBL problems typically range from a few sentences describing a perplexing event (e.g., sunburn at the beach) to detailed patient records. At UCLA, we use clinical cases presented in a narrative format in which details of patient data are embedded in the story of the patient, family, or larger societal issues. Students encounter the patient through his or her own words, actual medical records, the discussion among members of the health care team, the clinician's own inner thoughts, or the reactions of family members. Each case tells a story that is larger than the formal record of history, physical examination, and test results. A brother and his wife confront their own genetic risk when an 18-year old family member is diagnosed with cystic fibrosis. An elderly woman refuses to use a cane since it makes her look and feel old, but after multiple falls and fractures, the physician struggles to communicate the importance of prevention. A teenager borrows her boyfriend's Accutane (isotretinoin) to self-treat her acne and then finds out she is pregnant. In understanding and resolving stories like these, students develop learning issues that cover basic science, clinical science, behavioral and social medicine, and public health. The story provides the context for new learning.

Embedding evidence-based medicine skills. PBL is the principal venue where students gain experience with a "bundle" of clinical reasoning skills, including diagnostic reasoning, work-up planning, hypothesis testing, and application of pathophysiological principles. We have also revised our PBL process to purposely provide practice of core evidence-based medicine skills, including question-framing, online searching, article selection, critical appraisal, and application of studies to a specific clinical scenario (Guyatt & Rennie 2002). In addition to the typical clinical reasoning that occurs as a PBL case unfolds and the self-study required to address PBL learning issues, we have embedded specific evidence-based exercises that become progressively more complex. For example, early in the first year, students are provided with a single research article related to the PBL case, selected to demonstrate the types of literature used in basic- and clinical-science research, a range of study designs, or contrasting approaches to literature reviews. All students are expected to read the article, but one student is assigned the role of leading a discussion of methods and results. As the year progresses, the "journal club" activity is structured around the use of critical appraisal worksheets (Guyatt & Rennie 2002) for analyzing clinical trials and studies of diagnostic tests. In the second-year PBL, students learn to perform brief, focused reviews of current evidence following the format of the Best Bets evidence table (www.best bets.org) to argue a controversial decision embedded in the case through reference to the primary literature, or to identify and provide a critique of published guidelines.

Written learning issues. The first session of a new PBL case results in each student's taking on a learning issue to research for the group in addition to studying issues to be addressed by every student. Rather than just verbally reporting the results of their investigation at the second session on the case, students are required to write a 500–700-word explanation, complete with referenced citations. Students must post their write-ups to their group's online discussion board (hosted in the curriculum management system) at least 24 h before the second tutorial session to allow time for the students and tutor to read and respond to them. In addition, PBL tutors give feedback on posted write-ups using the discussion board, with more sensitive feedback being sent individually to the student via email. Students use a template to help focus their research around a specific question raised by the case and to remind them to apply their findings to the case rather than simply summarize what they read. To provide them with a global understanding of the different types of published medical literature and help establish sound searching skills, we provide a "sourcing matrix" that links specific question types to high-quality primary and secondary sources, including high-yield websites (e.g., MDConsult) and search engines (e.g., PubMed). This matrix distinguishes between questions about disease mechanisms and clinical outcomes as well as between patient-level questions and population/society-level questions (see question categories in Figure 5). For example, to gain a quick understanding of disease mechanisms, the matrix contains live links to online textbooks in the biomedical library's collection. In contrast, questions about the outcomes of treatment are linked to narrative and systematic reviews published in core clinical journals and to the Clinical Queries service of PubMed. The sourcing matrix provides students with an alternative to general purpose internet search engines and introduces them to the range of online sources of authoritative, published information directed at health professionals. By being required to prepare weekly papers based on library research, students develop skills in both written communication and evidence-based medicine.

Role-plays. We have incorporated a variety of role-plays into PBL to reinforce the importance of learning from peers. In the first year, these activities consist primarily of the tutor's taking the role of a clinician or patient during the second session for a case after the majority of learning issues have been discussed. Before the "patient" or "clinician" questions individuals in the group, the students have 10 min to preview the expected questions and to seek clarification from one another. During the role play, the tutor directs his or her questions to one of the students who did not research the particular topic. In the final block of the second year, students take on the roles of the attending physician, a patient, or family member, and a "patient explainer". The explainer has the task of explaining diagnostic or treatment plans to the patient/family member without using any medical jargon. Students also learn what is expected of them during clinical rounds in the upcoming clerkships.

Video presentations. Segments of the PBL case are presented via video to provide students with practice in listening to the patient's story or to engage them emotionally with the patient's experience of illness. The video can introduce students to other family members, demonstrate patient/physician interactions, or give a voice to patients' concerns (Balslev et al. 2005). Web-based, video-rich cases such as those produced by L.I.V.E. can provide students with a chance to observe history taking and essential physical examination procedures as they work as a team to complete a virtual history and physical examination (Kamin et al. 2001).

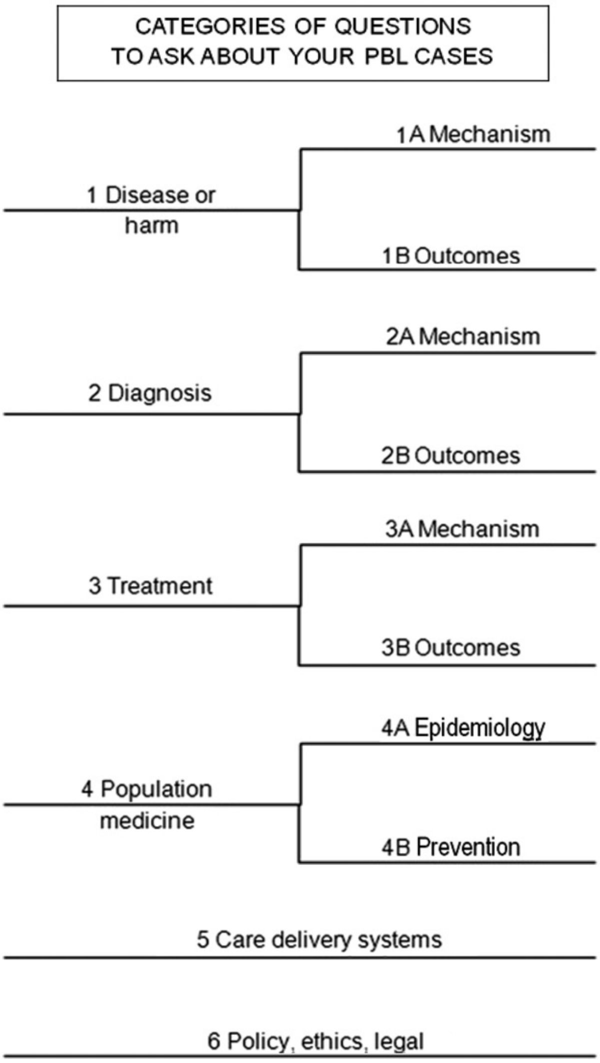

Figure 5. Learning issue categories. Students are asked to target their learning issues to one of these categories. The "sourcing matrix" then links these categories to appropriate primary and secondary resources to help students identify authoritative sources and develop effective searching strategies.

PBL plus vignettes. Multiple case vignettes are used across HB&D to promote generalization and practice beyond the single PBL case of the week. For example, in a week in which the PBL case diagnosis is COPD, a Friday lecture slot is devoted to discussion of five case vignettes involving shortness of breath produced by a variety of other "undisclosed" mechanisms. Students apply their knowledge to diagnosing these cases. The "Foundations of Medicine 2" block uses two PBL cases per session for purposes of comparison and contrast, e.g., same infectious agent in a child and an adult. Cases are presented in the biweekly doctoring small-group sessions using standardized patients to provide opportunities for students to practice skills essential to patient-centered care. Given the additional clinical vignettes used in the histopathology and anatomy laboratories, students have multiple opportunities during each week for "mixed practice" applying pathophysiologic concepts that they learn in lecture and PBL to systematically varied clinical situations, thereby avoiding the concern expressed by some that the context provided by a single PBL case can limit students' abilities to transfer what they are learning to new situations (Coulson et al. 1997).

Lessons for the individual teacher

In this article, we have outlined the broad goals that drove the development of an integrative pre-clerkship curriculum at UCLA and have described some innovative elements that may hold interest for other educators seeking to better integrate basic, social, and clinical sciences. While some of the approaches we describe require coordinated action from numerous individuals and departments, individual teachers can adapt many of the approaches we have used without overhauling existing curricula. We close with a consideration of curriculum integration from the perspective of the individual teacher.

Cross-disciplinary partnering

Of all the innovations we have explored in the course of developing the HB&D curriculum, pairing a basic scientist with a clinician knowledgeable in the objectives to be included in each block and committed to pre-clinical education has likely had the greatest yield, both in improving the relevance of the course content and in the satisfaction of both faculty partners. These pairings in our curriculum allowed pre-existing lecture materials to be streamlined, linked explicitly to clinical scenarios and integrated with the week's PBL cases. The cross-disciplinary faculty partnerships generate a great deal of professional satisfaction for the participants and produce outstanding integrated educational content.

PBL variations

We have described a number of interventions that are targeted to explicit learning objectives in the setting of PBL. As with cross-disciplinary partnerships, these innovations can be applied by individual PBL tutors. The learning issue write-up has become the framework on which we hang our numerous activities undertaken to enhance and expand upon classical, student-driven PBL. The weekly research for learning issue questions offers a setting in which students can practice high-yield sourcing of published medical information, improve their online literature searching skills, and learn to carry out critical appraisal of primary literature. Role-plays are easy for a tutor to initiate and have a high yield in adding new dimensions to the learning experience in the small group. One of the simplest role plays involves the tutor pretending to be a patient, family member or attending physician who asks each student to explain some aspect of the case that has been researched by the group between tutorial meetings.

Team-based learning

Finally, among our most successful innovations, and again, one that can be implemented by the individual teacher, has been to move detailed, highly visual content, such as histopathology and anatomy to computer-based, interactive, self-study modules that contain the core information content, links to explanations and definitions of terms, branching hot links to explore selected topics in greater depth, and the ability to drill down from the organ system through the cellular structure and even to the molecular level. Using a team-based learning approach, the teacher can require students to complete self-study modules prior to class, thus freeing up class time for application and discussion rather than knowledge transmission (Michaelsen et al. 2007).

Conclusion

A pre-clerkship medical school curriculum succeeds to the extent that its students arrive on the wards with an organized approach for analyzing their patients' problems and an ability to selectively draw on, interpret and apply information from the vast reservoir of material covered in the pre-clerkship years. This educational outcome has many facets and defies easy measurement. Frequently cited measures of curricular outcomes, such as national examination scores and student satisfaction provide little direct information on the student's capacity to apply the fundamental sciences at the bedside. Published data indicate a substantial attrition of basic science knowledge during the clinical years (Ling et al. 2008). However, in year-end surveys, students who completed UCLA's HB&D curriculum reported marked improvement in their own ability to integrate clinical and basic sciences as compared to prior classes who completed a departmental curriculum, while exhibiting the same level of performance on the United States Licensing Examination, Step 1, with higher than predicted scores for at-risk students (Wilkerson et al. 2007).

In summary, our fully integrated, spiral, pre-clerkship curriculum built on repeating interdisciplinary blocks and longitudinal threads has yielded encouraging results as well as some specific innovations that other schools may find valuable to adapt for use in their own settings. With much work in front of us, we are well along the road to providing clinical context for all of the fundamental science content in the pre-clerkship years. Recognizing the challenges to reliably measuring quantitative educational outcomes from our curriculum reform project, we remain cautiously optimistic that students will continue to perform well on standard examinations while being better prepared for a lifetime of clinical work and learning.

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