PBL for Ph.D.: A Problem-based Learning Approach to Doctoral Education in Biomedical Research

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The Van Andel Institute Graduate School in Grand Rapids, MI, was founded in 2005 as a doctorate training program housed within an independent biomedical research institute. The school's mission is to train future leaders in the cellular, molecular and genetic biology of human disease, with an emphasis on translating such research into effective clinical applications.

The principles underlying the new doctorate program's design are consistent with those arising from the Carnegie Initiative on the Doctorate, as reported in the 2008 monograph *The Formation of Scholars*.[1] According to those principles, a primary function of doctoral education is to develop scholars who will not only sustain the learning of prior practitioners of the art, but also mold the practice of that art into its future shape. These are the scholars the Carnegie report calls "the stewards of the discipline."

To generate capable stewards of biomedical research, we attempted to structure each pedagogical experience in ways that rehearse those skills essential to professional scientists. Although most of the work that leads to a Ph.D. is original research that is eventually compiled into a dissertation, many programs begin with a core curriculum to establish a foundational knowledge base upon which the research experience is built. For biomedical research, that core knowledge spans multiple disciplines, including biochemistry, cell biology, genetics, molecular biology, pathology and bioinformatics.

The magnitude of information in these fields is overwhelming, so it would be naïve to expect students to learn all of the content in each area. Moreover, the concepts of these fast-moving disciplines are not fixed; they are constantly evolving. Thus, it becomes less important for students to know all of the current facts and more important that they develop research strategies, critical-thinking skills and evaluation approaches for any research problem they might encounter. Given that content-focused instructional methods are weak in developing effective scientific reasoning,[2] we concluded that other pedagogical strategies would be needed to most effectively develop future leaders in biomedical research.

Key skills

We adopted a curricular approach that leads students to the core concepts of the disparate disciplines in an integrated manner, while also developing key skills for conducting scientific research. These skills include the ability to:

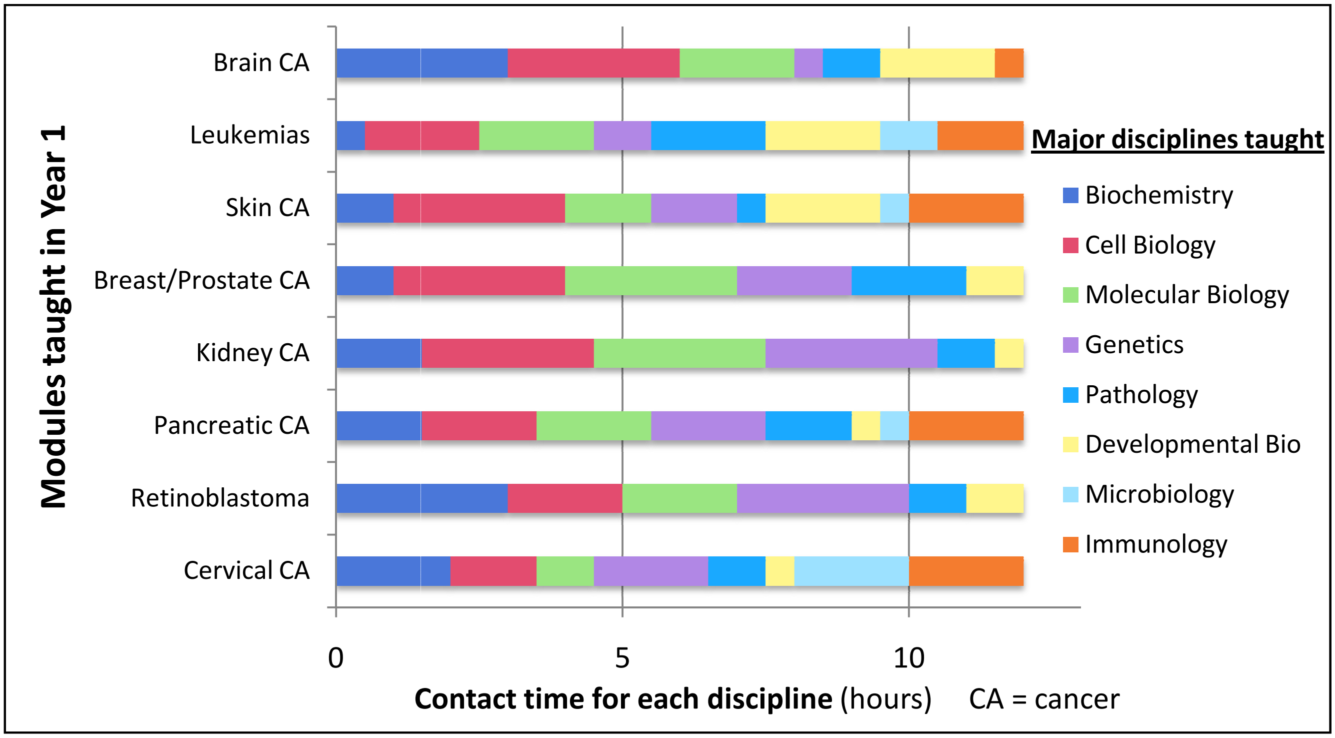
- Find new information relevant to a particular research question.
- Evaluate the quality of the information.
- Integrate this information into a conceptual model.
- Develop well-grounded hypotheses and specific aims to address the central question.
- Communicate those hypotheses and specific aims in the language and format customary for this field.

Our approach draws on problem-based learning (PBL) principles, originally developed for medical education[3,4] and also applied to business and law programs.[5-7] The essence of this approach presents the students with a series of carefully selected cases or problems relevant to the profession. The students—in small groups, guided by a faculty preceptor—use the problem as the context in which to develop learning issues that drill into the basic concepts underlying the case. The students then independently explore those issues, sometimes supported by lectures or readings, returning to the small-group setting to discuss their newfound understanding of learning issues.

Our adaptation of the PBL approach uses several features of medical-school PBL, but it differs in specific applications, some of which have been suggested for use at medical schools.[8] Rather than semester-long, discipline-specific courses, we organize our first-year curriculum into month-long modules, each focusing on a different human disease (typically some type of cancer). Early in each module, we pose a current research question relevant to that disease. The students' principal task is to draft a research proposal addressing that question. To accomplish the task, they are required to search out and understand concepts from various disciplines necessary for framing that proposal.

Our curriculum seeks to attain progressive and integrative concept and skill development. To track progressive concept development, we use a concrete concept map for the entire curriculum in which faculty track particular themes, ideas or concepts throughout multiple modules. At any given point in the academic year, a student can quickly discern whether a specific concept has been introduced previously or will be expanded subsequently. Additionally, the concepts are integrated, promoting learning through interwoven discipline threads across the spectrum of diseases.

Figure 1 depicts the discipline integration and shows the relative amount of time spent on each discipline in the integrated curriculum for first-year graduate students.



The progressive and integrative curriculum properties also apply to the professional scientific skills we seek to develop in our students. Throughout the course of two semesters, students pursue expanding levels of expectations. Initially, they frame only the hypothesis and specific aims. Later, they draft experimental plans, and eventually they augment anticipated outcomes and alternative approaches. These exercises supply students with ample opportunities to practice proposal writing and present realistic preparation for preliminary exams scheduled for the second year of study.

PBL places students and faculty in new and unexpected roles. The responsibility for learning falls directly and heavily on the student. This role fits our training program well because independence and perseverance remain goals for professional scientists. The faculty role minimizes concepts and information presentations, and expands in its tutor role. Faculty structure the overall learning experience, guide the process by which students learn and provide corrective checks on the students' understanding of concepts.

Facing challenges

In implementing this approach, we face challenges similar to those posed by PBL in the context of medical education.[9] One challenge is training faculty to employ this pedagogical method,[10] which is unfamiliar to those educated under more typical lecture and apprenticeship models. Researchers at VARI provide significant expertise as scientists, drawing from their work in the disciplines relevant to our educational mission. Our faculty development efforts push faculty to be explicit in their learning objectives while allowing flexibility intrinsic to PBL. Another challenge involves the assistance we provide to students, encouraging their transition to becoming effective self-directed learners[11] rather than passive recipients of content delivered to them in faculty driven lectures.

For medical schools, finding facilities and faculty preceptors can be expensive and time consuming, and the experiences in different small groups can vary widely.[12] Inherently, we circumvent such practical challenges because our doctoral cohorts typically comprise three to five students. The launch of this new doctoral program housed solely within a research institute allows us to employ a core curriculum free of the encumbrances and restraints imposed by institutional history or traditional academic calendars.

We have heard frequent calls for innovation and improvement in scientific teaching for undergraduate students.[13] The pitch has been made less frequently for substantial change to graduate education. The *Formation of Scholars* offers a basis founded in research for principles that guide those changes and best practices for implementing them.[14] Our use of PBL to structure the core curriculum for our biomedical doctorate program reflects one effort to do precisely that.

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