AN ILLINOIS SAMPLER

Teaching and Research on the Prairie

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and Antoinette Burton,
with Kyle Mays

UNIVERSITY OF ILLINOIS PRESS
Urbana, Chicago, and Springfield

From Desk to Bench
Linking Students' Interests to Science Curricula

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A first-year undergraduate student at the University of Illinois, majoring in chemistry, discovers through her new independence away from home that she loves cooking and baking. She begins to wonder about the changes she witnesses in food as she prepares it. For instance, when egg whites harden in the pan, why do they change from a transparent goop to a white solid? She hopes that her chemistry and biology teachers will cover some of her questions in class, considering how often she finds herself pondering about the science of food. But, by midsemester, her teachers haven't mentioned anything about food in either class. Unsure exactly how to proceed with her interests, she checks out a library book about the chemistry of cooking. It is dense and difficult to read, but she finds some of it interesting. She also attends a lecture about proteins (eggs have protein, she reasons), but given the introductory nature of her first-year classes in chemistry and biology, she is not yet equipped to understand much of the technical language used during the presentation. This student has everyday questions that require a technical, interdisciplinary scientific explanation. As she is beginning to understand, researchers at the frontiers of the scientific disciplines, indeed at the intersections of the scientific disciplines, are asking similar questions about her topic of interest: the chemistry and biology of food.

What this student needs in order to more deeply explore her interests is a bridge between her ordinary science classes (where she sits at the *desk*) and the world of scientific research (where she can explore her interests at the *bench*). As a researcher on the frontiers of chemistry and biology (Lu) and a chemistry teacher concerned with the attraction and retention of students to the science disciplines (Denofrio-Corrales), we sensed the disconnect between students' interdisciplinary interests and the content of the courses we co-taught. Co-teaching allowed us to form a partnership that has lasted over a decade and given us the opportunity to collaboratively work on this very issue. As scientist-teachers, we use our experiences from research practice to build a bridge for students, helping them go between the desk and the bench, and guiding them toward the best sources of information, academic courses, and research experiences to strengthen the link between individual interests and the traditional science curricula.

Learning Science at the Desk

Ten years ago, we asked roughly forty University of Illinois students majoring in physical or natural science fields a seemingly innocuous question—"What are your scientific research interests?" Most responses were cast in the hot areas of current scientific research—"cancer research" or "genetically modified foods" or "alternative energy sources." These undergraduates made up the first cohort of the Chemistry and Biology of Everyday Life (CBEL), a new chemistry course that links topics of everyday life like health, food, and energy to cutting-edge research studies in chemistry and biology. We hoped CBEL would create a bridge between desk and bench for a sliver of the students studying in the physical and natural sciences at our institution.

The first few semesters that CBEL was offered, we wanted to know what fascinated these undergraduates, vexed them, or got their curiosity thrumming away about topics that were rooted in their own experiences and in current scientific inquiry. We identified the curricula in introductory and intermediate major courses in chemistry and biology as centered on foundational concepts that were crucial to developing a solid understanding of the discipline but that gave students little insight into the research topics about which they were most passionate. We found a troubling gap between the content of sequential courses in a scientific major (such as Chem 101, 201, 301, and so on) and the students' actual scientific interests, most of which came from current, interdisciplinary research areas (Denofrio, Russell, Lopatto, and Lu, 2007).

How does this weak link manifest itself in the lives of undergraduates studying in physical and natural sciences? For instance, students who are interested in anticancer pharmaceuticals might never encounter the topic as a part of regular course content, or might have to take a host of courses before reaching a course that provides insight into cancer research or pharmaceutical drug design. Perhaps the wait for what is truly interesting is too difficult, or the content in the sequential courses too removed, for students to persist in their major. We do not mean to say that students will find the sequential courses in their majors unattractive, purposeless, or irrelevant. We believe, however, that their chronological structure (beginning with fundamental, historical scientific discoveries) and prescribed nature (often inflexible to consider the interdisciplinary nature of students' interests) can sometimes deter even the most tenacious undergraduates.

It remains impossible to make a standard set of curricula in chemistry or biology that follow a prescribed pattern, build a foundation of concepts and skills, and also serve as a relevant and interesting primer to current research in the areas each individual student finds fascinating. Therefore, we tried to complement the existing curricula by introducing students early to the excitement of scientific discovery at the frontiers of science, and to build CBEL as a companion to a traditional major plan of study in biology or chemistry. We tried to create a course with a nonstandard curriculum that was defined and driven by the students' interests and that linked their everyday interests to current science research taking place at the University of Illinois and other institutions.

Learning to Be a Scientist at the Bench

Considering how to link students' interests and course curricula made us reflect on our own concepts of *teaching* and *research*, and indeed to rethink the notion of *learning* in science. Completing a science major in chemistry or biology with the goal of becoming a research scientist means traversing a sequential set of courses designed to provide a foundational body of knowledge and a relevant skill set for eventual work at the bench in a laboratory. This education model adopts a cognitive perspective of learning. This means that learning is framed (1) as absorbing knowledge provided by teachers and textbooks and (2) as constructing ideas about scientific phenomena by inquiry and discovery. Knowledge is assumed to exist as concepts that reside in the minds of the teacher and her or his students, and is transmitted to the student through a series of exercises in classrooms and teaching laboratories that constitute the overt curriculum.

Through reflection on our own practices as scientist and teacher, we recognized that becoming a research scientist involves much more. Learning *to be a scientist* involves more than learning *science*. Learning to be a scientist requires a kind of apprenticeship experience, where one assumes the skills, dispositions, beliefs, and values of other, more experienced scientists by participating in the practice of scientific research. Through such participation, undergraduates learn traditions of scientific discourse, the norms of the disciplinary community, and the unique culture of research scientists—a tacit collection of beliefs and practices in the research community. This kind of knowledge is situated, and is not discrete. One cannot learn it by reading a textbook or solving even the most difficult of classroom exercises. Instead, it is passed down from generation to generation as a kind of situated curriculum.

Therefore there exists a second troubling gap, this one between the overt curriculum of chemistry and biology courses and the situated curriculum of learning to be a scientist. That is to say, there is a gap between the two types of learning, one being cognitive, and located in sites of formal instruction, and the other being situated, and located in sites of informal instruction, where authentic research is practiced. Our experience of this gap, and our desire to close it, grew out of our work as mentors to graduate-student researchers and teachers. The graduate-school model is an apprenticeship model, where students learn by participating in the practices of research and teaching, in collaboration with master scientists, master teachers, and "journeymen"—other apprentices at various stages of development. Our own practices have shown us how important and effective an apprenticeship model can be in learning how to be a scientist.

We wanted to impart this type of learning in CBEL, and to facilitate access to undergraduate research opportunities of the highest quality for University of Illinois students in the physical and natural sciences. A major step in building a bridge between desk and bench is encouraging students to be deliberate about preparing for and finding a supportive research environment that matches their major interests. Therefore, we sought to scaffold students' efforts by providing a model of a scientific research group within the CBEL classroom. We structured the class into small, investigative teams, each consisting of an integrative group of students across all four years of study, with the junior/senior students serving as exemplary undergraduate researchers and peer mentors to first-year and sophomore, less experienced students.

Building a Bridge between Desk and Bench

With the support of Howard Hughes Medical Institute (HHMI), the Department of Chemistry at the University of Illinois offered the first Chemistry and Biology of Everyday Life (CBEL) as a pilot course for about forty students in 2002. CBEL was not envisioned as either an honors course or as a replacement for traditional courses; instead, it runs alongside the sequential curriculum of chemistry and biology. It is an information center, making other science courses more meaningful; a triage, where each student's background and interests are analyzed; a matchmaker, where students' interests are matched to instructional materials; and a forum, where students can interact with others who have common interests. Perhaps most importantly, our students describe it as a bridge between classroom and undergraduate research experiences in their majors.

Undergraduates at all levels enroll in CBEL, and they are encouraged to take it early in their college careers and then reenroll each spring term until they graduate. Junior/senior, more experienced students serve as peer mentors and facilitators for first-year/sophomore, less experienced students. Throughout the course, instructors and peer mentors help students to develop necessary skills to investigate their own interests through activities such as mini-literature reviews, special topics discussions, journal article assignments, visits to laboratories, and attendance at scientific meetings. All exercises and assignments provide scaffolding for building to the final assignment; all work is shared with and reviewed by peers and instructors along the way.

Our approach in CBEL is to script the curriculum around students' interests, providing the skills to connect their interests to cutting-edge research, and to model the situated curriculum of science research practice through peer mentoring and experiential learning. The course mirrors a research group: it is cut into specialized teams, multidisciplinary, interest-driven, and responsive to cutting-edge research. CBEL is an insider's look at how science research works and a training ground for framing, articulating, and executing high-level analysis in scientific research. CBEL strengthens both the apparent and the hidden weak link between students' interests and science curricula.

To strengthen the link between students' interests and the curricula of their traditional courses, CBEL uses students' interests to write the syllabus and drive the direction of the curriculum. Soon after their registration, students are asked to identify their research interests in science. Content lectures, tailored to students' self-identified interests, are scripted by instructors throughout the term and given once per week to provide the background and vocabulary necessary to understand and analyze current scientific literature related to their interests. Instructors also facilitate open sessions called skill lectures, where we introduce the tools and skills needed to be an effective research scientist.

To build a bridge between the classroom (learning at a desk) and the research laboratory (learning at the bench), CBEL models a scientific research *group*. Bringing together a diverse set of students of different ages, years-in-school, and overall college experiences, the class is cut into smaller teams by way of students' self-identified interests. The teams are called subgroups, much as they would be in a laboratory research environment. Each student is placed into a subgroup based on several criteria: his or her scientific interests, number of times in CBEL, and undergraduate research experience. The subgroup is specific to some subject or topic that encompasses the members' interests, such as forensics or pharmaceuticals or alternative Energy. Less-experienced students use the subgroup as a site of informal learning. They ask questions about the situated curriculum of science: how to locate useful courses, how to enter a research laboratory, how to be successful as a researcher. Peer mentors transfer tacitly the values, assumptions, and beliefs that they have come to understand from their research experiences in a laboratory.

To infuse excitement and interdisciplinary questions into science learning at the University of Illinois, CBEL hosts sessions with guest scientists, whole-class activities, and field trips. Dialogue and discussion become commonplace in the CBEL classroom as students teach each other and welcome guest scientists who provide in-depth talks on current, cutting-edge research. A most exciting complement to traditional lecture, some scientists open their laboratory spaces for special CBEL tours. CBEL students have been fortunate to visit the Illinois Research Park, the Institute for Genomic Biology, the Beckman Institute, and many interdisciplinary research laboratories. We have also hosted field trips to industrial laboratories in Chicago, Indianapolis, and St. Louis and have accompanied our students to experience firsthand the excitement of scientific discovery at national professional conferences.

Strengthening the Bridge between Desk and Bench

In our ten years as scientist-teachers on this project, we have seen how CBEL complements, rather than competes with, existing sequential courses in science disciplines, such as chemistry or biology, by working tangentially with the traditional system. Dramatic, large-scale changes to traditional curriculum (even when they are informed by research) are often perceived as too costly and disruptive to implement. Therefore, we believe that CBEL is a possible interests-driven model for other research universities and in other disciplines. For example, why not create a Physics and Mathematics of Everyday Life course? The CBEL model is multidisciplinary. Such a course could also work to build the bridge and strengthen the links between classroom and research laboratory.

We also believe that there is a place for the CBEL philosophy within the traditional curriculum, and that even traditional curricula can take on an interests-driven perspective. In 2007, we moved successful CBEL modules into the mainstream chemistry curriculum with support from the University of Illinois Provost's Office. We called this module implementation the Chemistry Enrichment Project (CEP), and asked interested students to participate in extra mentoring and research-based activities. As in the standard version of CBEL, the CEP participants expressed enthusiasm for the activities and reported significant learning gains in research-related areas.

From our professional experiences, we have learned that to explore deeply individual interests, undergraduates need a bridge between ordinary science classes (the *desk*) and the scientific research laboratory (the *bench*). Rather than aiming to change the sequential model of science curricula, which remains an important foundation of undergraduate education, CBEL works in tandem with standard courses. We believe the future of undergraduate education lies in an interest-driven model that is widely portable across disciplines and can effectively and wholly integrate research and classroom experiences. As scientist-teacher partners, we seek to strengthen the link between individual interests and the traditional science curricula at the University of Illinois, by pointing the students toward the traditional courses that match their interests, making them more motivated to remain in science majors, and encouraging them to enter the research laboratory early in their undergraduate career.

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