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FEATURES

Defining the Scholarship of Teaching and Learning in Microbiology

Spencer A. Benson
University of Maryland-College Park

What is the scholarship of teaching and learning? In this article I describe several types of scholarship, give a brief historical overview of teaching scholarship, address the differences between teaching excellence and the scholarship of teaching, and list a set of properties one might use to define the scholarship of teaching microbiology. Lastly I describe some of the relationships between teaching and learning. Ultimately, there is no single definition for the scholarship of teaching and learning; rather, there are many overlapping definitions that are individual, discipline, institution, and situation dependent.

A Brief Background

The concept that teaching involves and requires scholarship is both ancient and new. Many of our greatest philosophers and scientists were first and foremost teachers (e.g., Socrates, Aristotle, Galileo) and it was through their teaching that knowledge was constructed. Aristotle once proclaimed, "Teaching is the highest form of understanding". More recently (1896), the University of Chicago's first president, William Rainy Harper, stated, "The young doctor sometimes forgets that the institution in which he works is under obligation to furnish the best possible instruction to the students whom it has gathered within its walls…If a man is unable to teach, he cannot rightly receive an appointment in the University" (7). Certainly in the first half of the 1900s, teaching was the primary purpose for public and private educational institutions. However, with the emergence and increased availability of public and private research funds, the nature and roles of the University and its reward systems changed (6) from one that focused on teaching to one that focused on research and the scholarship of discovery. In 1990, Ernest Boyer's seminal report *Scholarship Reconsidered: Priorities of the Professorate* (known as the Boyer Report) called upon universities to rethink what scholarship means (3). In the report, Boyer outlined four types of academic scholarship (Box 1). As defined by Boyer, the scholarship of teaching connects and encompasses all the other forms of scholarship and facilitates their perpetuation. Furthermore, it has been argued (9) that the scholarship of teaching is the most central and important type of scholarship.

The effects of the Boyer Report are well known. Today on nearly every campus there are faculty members who individually and in groups are actively defining, promoting, and doing the scholarship of teaching. Discus-

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Box 1. Four types of scholarship (3)

- **The Scholarship of Discovery**: the discipline research we do and publish.
- **The Scholarship of Integration**: the intellectual work and writings that allow oneself and others to construct, see, and understand the connectedness of all things.
- **The Scholarship of Application**: the application of knowledge to real world problems, for the betterment of worlds big and small.
- **The Scholarship of Teaching**: the works of helping others understand and construct knowledge so they may engage in the other forms of scholarship.

sions about teaching and the scholarship of teaching are occurring at many levels—within departments, teaching centers, campus senates, and professional societies. Often these discussions wrestle with the issue of how to define the scholarship of teaching. So what is the scholarship of teaching and learning at the local and personal level? Let us begin by clarifying what it is not.

What It Is Not

One thing the 1990 Boyer report failed to do was to clearly define the relationship between the scholarship of teaching and excellence in teaching. During the 1990s there was much discussion of whether excellence in teaching constitutes prima facie scholarship of teaching. Certainly, many excellent teachers practice scholarship of teaching. But excellence in teaching is not necessarily scholarship of teaching. *I use the term excellence in teaching to refer to individuals who through their pedagogy or personal attributes bring about increased student learning.* We all have colleagues and know of teachers who, by their distinct forms of pedagogy, deep commitment and caring, or unique personalities, are able to connect with students in special ways that stimulate and encourage them to learn. Such individuals are recognized as great teachers and are exemplars of excellence in teaching. But their teaching is not necessarily an example of the scholarship of teaching.

Does scholarship of teaching require excellence in teaching? Certainly not! Even though faculty members who engage in the scholarship of teaching strive for excellence and increased student learning, it is possible that when one practices the scholarship of teaching it may not result in increased learning, at least not initially. In my own attempts at the scholarship of teaching, not all of the ideas and things I have tried resulted in increased student learning. Many have had an effect, others have had no effect, and some even resulted in less student learning. This is analogous to my efforts in research (the scholarship of discovery), which focuses on achieving a better understanding of the antimicrobial agents present in Chinese herbal medicines. So, if the scholarship of teaching is not necessarily excellence in teaching and does not necessarily result in increased learning, what is it?

Recognizing the Scholarship of Teaching

In order for faculty, departments, campuses, and professional societies to recognize the scholarship of teaching, there needs to be a set of defining attributes. Lee Shulman, Pat Hutchings, and others have written extensively on the attributes of teaching scholarship (4, 5, 8-10). In addition, professional societies such as the Society for College Science Teachers (SCST) (11) and the American Association of Colleges of Nursing (AACN) (1) have published guidelines defining scholarship of teaching. Both the SCST and AACN guidelines are discipline specific. The role that a discipline plays in determining what constitutes the scholarship of teaching for that discipline is addressed in the writings of Mary Huber (8). To my knowledge no comparable guidelines have been developed for biology

or microbiology educators. What might a set of working guidelines look like for scholarship of teaching in microbiology?

In Box 2 I have listed a set of 12 properties I think define the scholarship of teaching microbiology. This list is adapted from many sources and is best viewed as a working list for future discussions. The list is neither inclusive nor prescriptive since there may be examples of the scholarship of teaching microbiology that have properties or attributes not listed in Box 2. In the next section, I discuss these properties in more detail.

A Closer Look at the 12 Properties

I suggest that the first five properties are the essential aspects of scholarship of teaching in all disciplines. The first step in the scholarship of teaching begins when reflective analysis takes a central role in the teaching process. Too often teaching occurs without reflection (or going "meta," to borrow a phrase from Pat Hutchings) (9). This is especially true at universities where the scholarship of discovery is the primary (and sometimes sole) measure for faculty performance. How often have we seen colleagues at the end of a semester assign final grades and close the book on the course until he or she teaches it again? Would we do this following 12 weeks of bench work on a research project—close the lab book and sigh with relief? Even worse is the faculty member who opens a file and removes the yellowed notes (or computer disk) from past semesters the day or week before the class starts. Although it is troublesome, we all know that at some institutions it is possible for a faculty member to be considered an adequate teacher by just teaching a class and covering the course content without ever thinking about the process of teaching.

When educationalists talk about metacognition ("going meta"), they mean that we need to periodically step back and deeply and critically reflect upon our teaching before, during, and after the course. Deep critical reflection is a fundamental activity for all types of scholarship. In the scholarship of discovery critical reflection is a necessity that is forced upon the researcher. Could one write a successful grant, paper, or review or design an experiment without deep reflection? Certainly not! Many faculty overlook or never see the need for self-reflection about teaching because of the absence of graduate training in how to teach, the private nature of teaching, and/or the perception that teaching is a low priority activity. To be a successful teacher requires one to reflect on one's teaching; only after deep reflection do the importance, challenges, and benefits of engaging in the scholarship of teaching become clear.

Box 2. Twelve properties of scholarship of teaching and learning in microbiology education

1. It involves reflective analysis by the microbiology educator
2. It involves documentation and dissemination of a product that facilitates the learning of key concepts in microbiology
3. It involves appropriate review and critique by other microbiology educators
4. It builds upon the work of other educators in the field of microbiology and other disciplines
5. It allows other microbiology educators to build and improve on it
6. It stimulates intellectual exchanges among microbiology educators
7. It is public; it is work that is shared with peers at all stages of its development
8. It is problem centric; it seeks to understand, solve, or advance knowledge about a problem in or related to microbiology education
9. It is work that is embedded in the principles and foundations of microbiology and microbiology education
10. It involves practical engagement in teaching microbiology
11. It fosters connections within microbiology and to other disciplines
12. It maintains fidelity to: the field of microbiology, the communities microbiology educators share, the educator's identity and sense of self, and most importantly, learning by students

Property 1. It involves reflective analysis by the microbiology educator

Beyond the obvious benefits of reflecting on our teaching, deep reflection often elevates teaching from a journeyman activity to a creative intellectual activity. When teaching is viewed in this way, it can be directly compared to the scholarship of discovery—the scholarship most of us know best. Thus, when practicing the scholarship of teaching, we develop teaching strategies (experiments); we review, evaluate, and share our experiences with others (publish); peers evaluate our strategies (peer review) and then develop their own (construction of more knowledge).

The act of sharing (properties 2, 3, 6, and 7) helps to differentiate the scholarship of teaching from excellence in teaching or scholarly teaching. One can be an excellent teacher and even a scholarly teacher without sharing or making public those things that confer excellence. Indeed, teaching frequently occurs without peer review. Peer review and sharing can take many forms, such as inviting others to visit our

Property 2. It involves documentation and dissemination of a product that facilitates the learning of key concepts in microbiology

Property 6. It stimulates intellectual exchanges among microbiology educators

classes, discussing class and teaching problems with peers, developing common exam questions, disseminating teaching tools by writing journal articles or giving presentations, and organizing discussions about teaching and learning. In each instance, a community of peer teachers is enjoined for support, review, and critique.

Community building and sharing are the centerpieces of the scholarship of discovery (research), and it should be remembered that scholarship of discovery was recognized and rewarded only when it became reviewed, critiqued, and public. For microbiology educators there are now many venues for public sharing and dissemination of peer-reviewed products of scholarship in teaching. These include the annual ASM Undergraduate Education conferences, the new Microbiology Education journal, Microbe Library curriculum resources, and various ASM listservs. In addition, a number of other professional science societies and groups have appropriate venues for publication of articles on microbiology education, and there are several on-line journals devoted to the scholarship of teaching and learning (see the resources section at the end of this article). Each of these venues stimulates exchanges among microbiology educators.

Property 3. It involves appropriate review and critique by other microbiology educators

Property 7. It is public; it is work that is shared with peers at all stages of its development

For me, properties 4, 5 and 8 best characterize the scholarship of teaching. All of us routinely borrow or steal from our colleagues teaching tricks and ideas, which we modify to fit our teaching needs and environment. In doing this, we are building upon the work of others. Indeed one of the main reasons for attending the ASM educational conferences is to collect new ideas that we can adapt to our teaching. Many of us experience personal satisfaction in developing educational ideas or adapting existing ones to our needs. One of the rewards for developing or adapting a new teaching idea is when a colleague values it enough to adapt it for use in his or her class.

Property 4. It builds upon the work of other educators in the field of microbiology and other disciplines

Property 5. It allows other microbiology educators to build and improve on it

The problem-centric vision of the scholarship of teaching is well presented and described in the writings of Randy Bass, a faculty member in American Studies at Georgetown University (2). His description of the scholarship of teaching clearly reinforces its similarity to the scholarship of discovery. For example, a research project might ask, "How do bacteria know to move toward food and away from detrimental environments?" In the scholarship of teaching, the question might be, "How does adding a virtual lab on determining colony forming units affect students' understanding of the concept of dilutions?" Both situations use a similar problem-oriented framework, and in each case the scholar defines a problem and then designs approaches or experiments to solve or better understand the problem. It is worth noting that Bass's view of the scholarship of teaching stems from a professional lens (American Studies) far removed from microbiology; yet he uses a framework all scientists recognize and employ in the scholarship of discovery.

Property 8. It is problem centric; it seeks to understand, solve, or advance knowledge about a problem in or related to microbiology education

Properties 9 through 12 are important but may not be essential to the scholarship of teaching. However, they do help to frame the scholarship of teaching in a broader context. All disciplines contain attributes (facts, principles, ideas, and connections) that define the discipline and make it recognizable by students and practitioners. For students to understand microbiology and to be able to think like a microbiologist, they must have an understanding of and a feeling for these attributes. Thus, the scholarship of microbiology teaching needs to encompass and be connected to the fundamental characteristics that define microbiology. For example, scholarship that seeks to understand how class length affects learning is an appropriate problem within the scholarship of teaching, but it would not be specifically connected to the discipline of microbiology. In contrast, scholarship that seeks to understand how length of a lab period affects learning is directly linked to the discipline of microbiology education because the laboratory experience is one of the fundamental attributes of microbiology and microbiology education.

Property 9. It is work that is embedded in the principles and foundations of microbiology and microbiology education

The scholarship of teaching microbiology needs to focus on the act of teaching microbiology. While articles and position papers on science education or the need for more or different microbiology education are types of scholarly works, they may not represent scholarship of teaching microbiology. However, articles describing solutions to specific problems or issues in microbiology education and articles describing teaching tools that result in improved teaching or learning of microbiology are clear examples of scholarship in microbiology education.

Property 10. It involves practical engagement in teaching microbiology

Helping students make connections between facts, knowledge, and the world outside of the classroom is a goal of good teaching. Often in the scholarship of teaching one seeks by design, purpose, or consequence to highlight and accentuate such connections. Among all of the biological sciences, microbiology is the one that is most deeply connected to the world we live in; everything on the planet and in our own lives is directly or indirectly affected by microbes. Thus, it is often possible to develop connections that extend beyond microbiology to real world issues, problems, and solutions. In some instances, building these connections can also provide insights into and better understanding of how we teach microbiology and how students learn microbiology.

Property 11. It fosters connections within microbiology and to other disciplines

The final property is taken from the writing of Lee Shulman (10) and speaks to the moral integrity and fidelity of teaching. Some of the fidelities are obvious. When we teach microbiology, it should be the focus of our class—not molecular biology, cell biology, immunology, or some other subject. The material taught should be consistent with current knowledge in the field of microbiology and should be aligned with the ASM educational core themes and concepts. Property 12 also underscores the importance of finding our own teaching voice and developing it. Like painters, musicians, actors, and other artists, good teachers need to develop a style based on their strengths. In many cases exceptional teachers are artistic, and the linkage between artistic ability and excellence in teaching may not be coincidental.

Property 12. It maintains fidelity to: the field of microbiology, the communities microbiology educators share, the educator's identity and sense of self, and most importantly, learning by students

Finding one's teaching voice and developing it takes time, effort, practice, and reflection. I am envious of my colleagues who are able to use humor or drama as a mechanism to teach. However, whenever I attempt using either, I fail; generally the class doesn't get it, and I am left with a classroom filled with blank stares and silence. The harder I try the more disastrous the results. With reflection I have come to realize that the reason I fail is that humor is not part of my natural teaching presence. Thus, it is not surprising that when I disregard fidelity to my identity and try to be something I am not, my teaching does not work. (But, I am still envious of my colleagues who can pull this off.)

Lastly and most importantly scholarship of teaching microbiology needs to embrace the fidelity of student learning and critically assess deep as well as shallow learning. It should not rely solely on convenient or easy metrics for measuring how well the student has learned the fundamentals of microbiology.

Teaching and Learning

During the last decade, the scholarship of teaching has evolved into the scholarship of teaching and learning. This linkage in part resulted from a better understanding of how learning occurs, increased use of activities that enhance learning, increased focus on learning outcomes as opposed to learning processes, an atmosphere of greater accountability, and the activities of campus teaching centers that have helped to focus faculty efforts on student learning rather than content delivery. While we strive as educators and scholars to connect teaching and learning, they are not inherently coupled. Learning can occur in the absence of teaching and too often teaching occurs without true learning. Figure 1 illustrates four types of connections between teaching and learning. In A the two are disconnected; what is being taught may not be what the student is learning. Unfortunately this too often represents what occurs in university classrooms. In this scenario, what the student often learns is how to get a good grade on the next test, and the teacher often functions as a journeyman—untrained, or at best self-trained—whose goal is to get through the class or to cover the course material. It is unlikely the teacher functions as a scholar or artist who strives to improve the course and in doing so perfects his or her teaching craft. In B the two processes are separate but connected by the teacher's acts. What is taught is helping to direct what is being learned, although the process is unidirectional. This represents what occurs most often in the university setting, especially when the class size is large. In C, the two processes remain separate but connected and the flow of information and ideas is no longer unidirectional although it may be biased in the teacher-to-student direction. This type of relationship occurs more easily when the

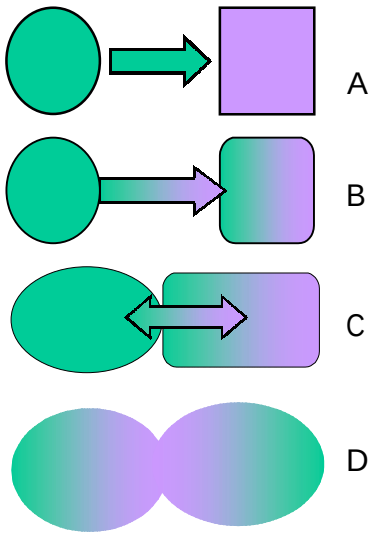

FIG. 1. Teaching and learning relationships

class is small or when teachers work one-on-one with individual students. It represents a type of educational experience that is often powerful and transforming. In D, teaching and learning are seamlessly connected. This may be the "holy grail" of teaching that we seek but rarely occurs. In it both the teacher and student share the roles of teacher and learner and learning is bidirectional.

In actuality good courses taught by dedicated teachers have all of the situations depicted in Fig 1. The amount of each type is determined by external factors such as class size, room lay out, and time of day, as well as by internal factors such as the nature of the students, the teacher's comfort with the course material, other demands on the teacher's time, and the teacher's personal visions of teaching and the scholarship of teaching and learning.

Summary

In this article I have given a very brief historical overview of the scholarship of teaching, placed it in a context with other forms of scholarship, and provided a set of properties one might use in defining the scholarship of teaching microbiology. Defining the scholarship of teaching microbiology is not a simple task because the scholarship of teaching is best defined by a set of attributes that can be general (reflective, public, connected), discipline (lecture, laboratory, practical skills) and situation specific (institution type, class size, student type, teaching platform [e.g., traditional versus distance education]). Perhaps this is why it has been difficult for departments and colleges to embrace, recognize, evaluate, and reward the scholarship of teaching and learning. My hope is that this difficulty will eventually be seen as a challenge to conquer rather then a barrier that separates and supports the old adage "Those who can do; those who can't teach." For me the challenges of good teaching and the scholarship of teaching are more difficult and intellectually challenging than those of the scholarship of discovery (research). However, in reflecting on the commonalities and the means for dealing with the challenges shared by both types of scholarships, I have become a better teacher and a better researcher.

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Resources for Scholarship in Microbiology Education

ASM's sites for publishing scholarship in microbiology teaching:

- Curriculum resources http://www.microbelibrary.org/Curriculum/page2.htm
- Microbiology Education journal http://www.microbelibrary.org/Journal/frame4.htm
- Focus on Microbiology Education newsletter http://www.microbelibrary.org/newsletter/frame5.htm
- ASM's Board of Education and Training http://www.asmusa.org/edusrc/edu1.htm
- ASM Core Themes and Concepts for an Introductory Microbiology Course http://www.asmusa.org/edusrc/edu32a.htm#Core

Carnegie Foundation for the Advancement of Teaching

- http://www.carnegiefoundation.org/
- An Annotated Bibliography of the Scholarship of Teaching and Learning in Higher Education http://www.carnegiefoundation.org/CASTL/highered/bibliography.htm

American Association for Higher Education

- Webcenter http://aahe.ital.utexas.edu/
- AAHE Bulletin http://www.aahe.org/bulletin.htm

Online Journals on the Scholarship of Teaching and Learning

- The Journal of Scholarship of Teaching and Learning (JoSoTL) http://www.iusb.edu/~josotl/resources_on_sotl.htm
- Inventio http://www.doiiit.gmu.edu/inventio/

The Globalization of This Microbiology Educator

Leigh Callan
Floyd College

A few years ago, one of my students completed a learning and sharing activity (1) that described a medical mission to Africa. The student's report was fascinating and inspiring to the other students and was compelling to me. Later that semester I attended the ASM General Meeting , where I went to presentations given by top-level epidemiologists and researchers from the Centers for Disease Control and Prevention as well as cutting-edge investigators from around the world. As I listened to these speakers, the course content that I include for my students in the areas of environmental biology and public health, especially in the realm of pandemic epidemiology, became very real to me. After the meeting, I began thinking about my student's report of her African experience and about the ASM sessions I had attended. I realized that most of my students will never leave Georgia, and it became very clear to me that it is my duty to try to help them think "globally"—to realize that things that happen elsewhere in the world can impact them and that they can find ways to impact others.

Fortunately, the University System of Georgia is committed to internationalizing the curriculum. As part of this policy, the System offers international faculty development seminars. Faculty must apply to the program by stating how they will use the knowledge gained to enhance teaching, the curriculum, research and scholarship, professional associations, and community service. I decided to apply for a three-week seminar in Ghana. I chose Ghana because that area of tropical West Africa is very much involved with the problems related to emerging infectious diseases and public health. The emergence and expansion of HIV in this area is a major example. My visit could teach me first-hand about the political, economic, cultural, and environmental influences on public health and disease containment. I could also learn how emerging diseases have influenced the regional economy and culture.

The theme of the seminar involved tradition and modernity as they coexist in present day Ghana. Lecturers included experts in sociology, history, politics, economics, the arts, education, women's issues, and other areas. Notice that the emphasis was more on the social and cultural disciplines than biology. Yet the site of these learning activities was the University of Science and Technology at Kumasi. Indeed, we were housed at the School of Medicine guesthouse. During my stay in Ghana, I not only learned from the seminar speakers, but I was also able to learn independently by interviewing a number of Ghanaians. In this article I describe some of what I learned. My complete travel log with commentary and analysis is available at http://www.fc.peachnet.edu/floyd/academics/biology/lc/fds/fdstitle.htm. For more information about Ghana, visit http://www.library.yale.edu/~fboateng/fbhp.htm. At this sight you can also find additional links to the Library of Congress site regarding health care in Ghana.

The Travel Experience and Public Health in Ghana

I began learning about Ghana in a very personal way even before I left home. My travel preparations included a battery of shots and other medical preparation, as I was going into a "hot zone" for tropical diseases. Although yellow fever was the only immunization required by the government, many others were suggested. I took malaria medicine and, in addition to yellow fever, was immunized for hepatitis A, hepatitis B, typhoid, and even polio (it had been 40 years or so since the "originals"). Thank goodness at least my tetanus and diphtheria immunizations were current. I also purchased enough insect repellant to drown in and a mosquito net suit! You can't accuse me of not being prepared.

Ghana is on the Greenwich meridian and just north of the equator. Formerly the Gold Coast, it was the first African country to gain independence from Britain (in the 1950s). The climate is hot year-round (around 85°F). It is one-third rain forest, but the only untouched forest remaining is in the national park, which we were able to tour by walking on rope bridges suspended 80 feet high, crossing the canopy.

Our group stayed in urban areas yet rode through rural areas between destinations. My inexperienced eye marveled at the prevalence of "free range" chickens and goats everywhere amongst the shacks in both rural and urban areas. Cooking occurred over open fires in the dirt or mud areas between hovels. There was always the smell of cook fires and the sound of roosters wherever we were. Laundry could be seen spread out and drying on the ground—right on the sandy, red clay surface. Modern conveniences were available to us, as we had comfortable and clean lodging in the cities. But we were subject to periodic utility outages.

Each village we passed through had

Crossing the canopy in Kakum National Park


Villiage children observing the observers

a central well from which all villagers draw their water. The bare earth is deliberately kept free of vegetation in order to keep the insects, lizards, and other animals away from the homes. A few isolated trees are maintained. These are often named and "honored." Open public latrines are common. We observed children bathing, lathered with soap, and then rinsing from water in a bucket carried to the drainage ditch alongside the road.

While touring a premier primary and junior secondary school, we were told that the school had won many awards. Particularly of interest to me was the award for Environment and Health. This means that good sanitation and health standards are maintained at the school and taught to the students to carry home. The students get a prize of pretty notepaper when they pass their health test. There were health posters everywhere. They addressed polio, Guinea worm, tuberculosis, oral rehydration therapy, and AIDS. The AIDS poster read "Mommy, Daddy, what happens when you die of AIDS? Please keep a faithful Partner." I realized that the perception of AIDS, hemorrhagic fevers, and drug-resistant organisms as the major health problems in West Africa was misleading; these diseases are only part of the public health picture. Basic issues—continuing problems with poverty, poor sanitation, lack of access to health care, and lack of knowledge and understanding amongst the populace regarding health practices—are very real, all-pervasive, and ongoing obstacles to disease prevention.

I talked to a pharmacist and other healthcare professionals about the AIDS situation. The pharmacist said that less than 1% of the population is sick with AIDS and the biggest concentration of them are in Kumasi, Ghana's second largest city. He said that there is extensive education in schools and enforcement of laws requiring the use of condoms by prostitutes. He also emphasized that polygamy is accepted; his father had 3 wives and 7 children. In an interview with Dr. Ohene Adjei, the Chairman of Clinical Microbiology in the School of Medical Sciences, I learned that all blood donors are tested and 13% are HIV positive. AIDS education is not done through the media of TV and radio because it is not effective (too few people have TV or radio). Instead, public health officials go to the villages, as well as to churches and schools, for special gatherings. Our seminar leader, Dr. E. Osei-Kofi, was formerly head of the Kumasi Red Cross, and I asked him about the blood donor pattern. He said that there are some professional blood donors but that the Red Cross does blood drives at schools, churches, and other community organizations. In his opinion, the pool is a good cross-section of the population. Although HIV infection is certainly a major concern in Ghana and West Africa is theorized to be the initial reservoir, the spread of HIV seemed to occur mainly along the trans-Africa highways toward the central and southeast regions of Africa where the statistics now show such devastation. I did notice one billboard about AIDS: it said the best protection against AIDS is good Christian values; the Salvation Army put it up.

AIDS is, of course, a growing medical problem in Ghana, but not to the "headline" proportions seen in other African nations. And there have not been any outbreaks of the dreaded hemorrhagic fevers (Lassa fever, Rift Valley, Ebola) so far in Ghana. Yet the health care system of Ghana struggles to meet the continuing basic needs of the populace. In the past, all government services (e.g., medical, education) were provided to Ghana's 18 million people at no cost. Currently user fees are assessed, but they are hard to collect. The government medical facilities are poorly equipped and staffed. In 1992, 800 physicians worked in the public sector and 300 in private hospitals. There are private church-sponsored hospitals and private clinics, which have better services but are very costly. Doctors and nurses in the public sector get an "allowance," yet are expected to work many hours of overtime for no extra pay. In recent months, the doctors went on strike and won payment for overtime duty. During our visit, the nurses walked out as well, and much media coverage was concerned with the political controversy and public difficulty this caused.

One day we stopped at a clinical laboratory and pharmacy (often called a "chemical shop" here). The proprietor told us that the hospital doctors (government funded) may diagnose and prescribe a certain medicine, and the hospital will provide the first few doses (they don't have enough to distribute the whole amount). Then the patient may (or may not) come to the pharmacy and buy a few more pills (as many as they can afford at the time). Then, most likely when they begin to feel better,

Accessibility of health care facilities

Chemical shop and pharmacist in Ejisu

they will not or cannot pay to get the rest. As we microbiologists know, this adds selective pressure for developing antibiotic-resistant organisms.

I also met a gastroenterologist from Stuttgart, Germany. He was in Ghana to study the diagnosis of tropical disease, since he had seen one case of malaria and one case of shistosomiasis in his community at home. He was treating patients in exchange for knowledge gained at the teaching hospital. Patients from "filter clinics" or "polyclinics" are referred to the teaching hospital. He said that the equipment is not as up to date as he is used to. Procedures that should only take 15 minutes take a couple of hours. On one occasion he lost his temper because the procedure had to be stopped twice because all of the needed items were not in the room. He also remarked that the windows were poorly constructed; there were open cracks between the wall and the windows, birds immediately outside, and bird droppings on the glass of the windows—a very risky environment for carrying out surgical procedures.

Interviews Regarding Microbiology Education and Clinical Microbiology

In my self-initiated tour of the medical school, I was privileged to meet and interview two brilliant professors who were very open in their descriptions of the status of medical education and health services in Ghana.

I asked Dr. Wirewe Brobby (Dean of the School of Medical Sciences, University of Science and Technology, Kumasi) about the infectious diseases, immunization procedures, and wound infections common to Ghana. He said that malaria, pneumonia (mostly Streptococcus), parasititis, and River blindness (tsetse fly is the vector) are the major infectious disease problems. He did not mention AIDS or polio, which others had mentioned, but did comment on a recent increase in tuberculosis. He told me that the general population is required to get polio, tetanus, and measles vaccinations in their first 3 years, and as a consequence tetanus is not a common wound infection. Gas gangrene is sometimes observed, as is cerebrospinal meningitis. Dr. Brobby also said that it is typical to give prophylactic antibiotics before and after surgery and that there are many penicillin-resistant strains of Staphylococcus. Culture and sensitivity tests are regularly performed.

When I asked Dr. Brobby about medical training in Ghana, he told me that medical school takes 6 years: 3 years of preclinical training and then 3 years of clinical training. Applicants must have a degree from the university before being accepted to medical school. Acceptance into medical school is very competitive, as only two medical schools are present in this country of 18+ million people.

School of Medical Science, University of Science and Technology, Kumasi, Ghana

I asked Dr. Ohene Adjei (Chairman of the Department of Clinical Microbiology in the School of Medical Sciences, University of Science and Technology at Kumasi) related questions as well as some questions that were more specific to clinical microbiology. I was interested in learning more about the training in microbiology received by medical students. Dr. Adjei told me, "The student comes to the school with a general knowledge of biology, chemistry, and physics. In the first year of medical school they get General Microbiology. Then in the third year, a little repetition of the basics for review, then details on bacteriology, mycology (mostly dermatomycoses), parasitology, and virology. They have a 4-hour practical exam every Friday, identifying unknowns. There is a study lab on campus and a clinical teaching lab at the teaching hospital. Each has an autoclave, a few microscopes, and means of incubation. There is basically the same equipment at each lab, but it is not standardized. The private diagnostic labs are not standardized either."

When I asked Dr. Adjei about specimen processing, his responses echoed Dr. Brobby's comments regarding antibiotic resistance. From blood culture, clinical microbiologists most often isolate *Staphylococcus aureus*, which is often resistant to penicillin, as well as *Streptococcus sp.* and various coliforms. They currently use second-generation cephalosporins and sometimes erythromycin or chloramphenicol to treat these infections; they have not yet moved to vancomycin. In respiratory aspirates, *Streptococcus pneumoniae* is often isolated and some are resistant to penicillin. *Shigella sp.* and *Salmonella sp.* are common in stool specimens; he was not sure if they have *Escherichia coli* 0157, because they have no way to test for it. The most common isolates in cerebrospinal fluid are *Neisseria meningitides, Streptococcus pneumoniae, Hemophilus influenzae,* and *Salmonella*; the

Dr. Ohene Adjei, Clinical Microbiology Professor, School of Medical Sciences, in his teaching laboratory at UST

most common wound isolate is *Pseudomonas*, which is developing resistance to gentamycin. Dr. Adjei indicated that they use the Kirby-Bauer disk diffusion technique to test antibiotic sensitivity and that misuse of ampicillin and tetracycline has led to the development of bacterial resistance to these antibiotics.

According to Dr. Adjei, infection control is carried out by "…a Health Management Team composed of public health nurses and a community health doctor. If there is a problem, they investigate, send a sample to a lab, and then advise the area what to do." This health team is under the jurisdiction of the Minister of Health.

I also asked Dr. Adjei about research activity in Ghana. He said, "There is a need to team up with researchers on 'the outside' to lend validity…" and that there is much research that needs to be done. For instance, there is a "…need to track down and follow up on what resistance is in a community due to the misuse of antibiotics. Also, we don't know whether we have *E. coli* 0157 or not...or even *Campylobacter sp*. We need a mechanism to determine the specific degree of resistance of *Streptococcus pneumoniae* or *Neisseria gonorrhea* to penicillin. If we can support our research with the validity of outside help, then our findings become news and are paid attention to. Publication in journals is not easy due to the lack of internationally accepted equipment. We would like to link with someone from outside to make our research more credible."

Computer access is also a problem for researchers in Ghana. "We have a common email address at one site on campus. I would have to go to the library to check it everyday. We don't have the capability to do an extensive search of the literature to see what has been done before. Phones are few among faculty and the existing phones are hard to hear. Often, to get in touch with a faculty member, you have to drop by their house."

The Impact

I am a biologist who has taught health science biology (Anatomy & Physiology and Microbiology) to prenursing, dental hygiene, and other health science students at the two-year college level for 25 years. My goal in attending the seminar in Ghana was to observe and learn about public health in Ghana and bring back to my students some first-hand information about newly emerging and reemerging disease patterns and how the populace responds to medical issues. I was able to do that and more. Little did I realize that the exposure to teachers and learners in the social and cultural disciplines would contribute immensely to my understanding of all-inclusive human issues, both here and abroad. I am now able to deal with my students in a different way, understanding local cultural differences as well as international ones. Currently I have seven international students in a group with 45 local students, and I am better able to recognize and bridge some of the different approaches they have to learning.

This opportunity was a transforming event for me. Being a novice traveler at my age (52) and experiencing a developing country for the first time, I knew I would have to draw on all of my coping skills. Yet I knew this would be the chance of a lifetime. It was even more than that. Now I know that the Chancellor's initiative to internationalize the curriculum doesn't just mean to add a bit of global perspective to the subject matter in the discipline of expertise, but to truly enhance the faculty member's understanding of the worldwide human experience in all disciplines. I urge all of you to pursue this type of opportunity and take full advantage of it.

Reference

1. **Callan, L.** 1999. Student-driven delivery of microbiology. Focus on Microbiology Education **5**(3):5–6. [Online.] http://www.MicrobeLibrary.org/newsletter/newsletter2.pdf.

Upcoming Events

Summer 2001 - Microbial Discovery Workshops:
July 18-22 University of Texas Medical Branch, Galveston, TX
July 25-29 University of Wyoming, Laramie, WY
http://www.asmusa.org/edusrc/edumdp.htm

Education Meetings:
19-22 June. 23rd Annual Association for Biology Laboratory Education (ABLE) Conference. Chicago, Illinois http://www.zoo.utoronto.ca/able/

15 - 28 July. Project Kaleidoscope (PKAL) 2001 Summer Insitute 2001 Snowbird, Utah http://www.pkal.org/curricul/2001si/index.html

7-10 November. National Association of Biology Teachers 2001 National Conventio. Montreal, Quebec, Canada http://www.nabt.org/convention.html

Some Surprises

Peg Heimbrook
University of Northern Colorado

Early in the semester I asked my students to list three things about microbiology that surprised them. For me, it was a way of taking attendance on that particular day, but it revealed a number of things about microbes that I take for granted and also pointed to the attitudes students have toward learning and linking new information to previous knowledge. From the list of about 200 surprises, I have gathered these.*

Many of my students were surprised at the diversity of microbes,

- *I didn't realize bacteria could be either aerobic or anaerobic. It's kind of scary/interesting knowing the little guys can live anywhere.*
- *I didn't know that there were quite so many different types of bacteria.*
- *I didn't realize that microbes are everywhere and that there are so many of them.*
- *That some people have methane-producing bacteria in their gut.*
- *There is so much complexity to these single-cell organisms.*
- *I was quite surprised when I looked at farm water in the lab and saw so many creatures.*

and by the fact that most microbes are not pathogenic.

- *I was a little worried about having to work with so much bacteria, but my paranoia has turned into more of a "wow," feeling than a freaked-out feeling.*
- *I always thought microorganisms were bugs/germs, I never knew they recycled and did so much other good stuff.*
- *I didn't know fermentation had to do with microorganisms. I knew yogurt had bacteria but didn't know sauerkraut and pickles did.*
- *That most microbes are not infectious.*
- *I didn't know that most bacteria are harmless and actually good for living things and the ecosystem of the earth.*

Many students found the anatomy and physiology of microbes interesting, especially their reproductive rates.

- *I am surprised that bacteria will grow in such a small amount of time.*
- *I didn't know that the flagella of some bacteria move cylindrically, like a propeller.*
- *I couldn't believe that one tiny drop of bacteria could produce such results in the lab. It doesn't seem like such small amounts would grow that much results and so fast.*
- *I didn't realize that microorganisms could grow so quickly.*
- *I found the types of capsules and their effect on gram positive and gram negative interesting. The Spirulina example helped make it interesting.*
- *How geared microorganisms can be for survival, such as the use of spores.*
- *I was surprised to learn how flagella works. It is interesting that it freely turns, instead of wagging back and forth, as I was previously taught.*
- *The complexity of bacteria anatomy!*
- *How quickly bacteria grew on my culture plate and slants.*
- *I am surprised how complex microorganisms can be.*
- *It was surprising to learn how long endospores can live even after they are all dried out.*
- *I am surprised at how resilient bacteria are.*
- *I think the whole structure and function of flagella are really neat.*

I also learned from this exercise that some students appreciated an historical perspective,

- *That most of the founders of Microbiology weren't even scientists or at least not biologists.*
- *That Pasteur developed the first rabies shot using dried serum from a rabid rabbit.*
- *Where the word inoculum comes from. (in ocula, in the eye)*
- *I was surprised to see how influential Pasteur actually was. All you ever hear about him is Pasteurization, but he contributed a lot more.*

that they were able to make connections to other disciplines,

- *I didn't know microbiologists did so much agriculture, genetics, and industry etc.*
- *I was surprised to learn that microbiology is so widely used. I thought that it was only used in the medical and science field, not everyday life.*
- *One thing that I didn't expect from microbiology is that it was that close to genetics.*
- *The number of different fields that are linked to microbiology.*
- *A lot of majors have to have it, or at least more than I thought.*

that they learned some things of practical importance to their lives,

- *Finding out that the anti-bacterial microbiology products we have today could actually hurt us in the end because of mutant strains forming.*
- *Learning what bacteria is responsible for a disease.*
- *I am going to be able to finally, with authority, tell my mother-in-law that when she serves off tasting hamburgers for lunch that it can still make you sick, even if she's cooked it for thirty minutes!*
- *Untreated rabies is 100% fatal.*

as well as some interesting topics for dinner conversation!

- *I am surprised bacteria are so closely related to human cells.*
- *One gram of feces contains 10^{12} cells of bacteria—gross!!!!!*
- *In one gram of feces there are 10^{12} microbes!!*

Finally, some students used the exercise to tell me their feelings (directly or indirectly) about the course

- *I'm excited about all of the hands-on stuff we are doing.*
- *I find this class to be really interesting which I did not think it was going to be.*
- *I am surprised I liked the class and find it very interesting. I thought it would be boring fortunately I was wrong.*
- *I was also surprised that my lab teacher would be the professor from lecture.*
- *I already found some one to sell my*

book to.

I encourage you to try a similar exercise. Perhaps your surprises will be as informative as mine.

**I have made few editorial corrections to the student comments.*

Plan to attend the

9th Annual Undergraduate Microbiology Education Conference

May 17-19, 2002
University of Utah,
Salt Lake City, UT

Spend three days with other microbiology faculty in an intimate setting conducive to networking, discussion, and small group interaction. Workshops, plenary sessions, and breakout groups allow participants to acquire new ideas to incorporate in the classroom, learn ways to promote the scholarship of teaching, and meet faculty from diverse insitutions.

For information on registration and submission of abstracts, visit http://www.asmusa.org/edusrc/edu4c.htm.

NEWS AND VIEWS

Curriculum Guidelines for Microbiology Majors: Working Recommendations

Neil R. Baker
Chair, Undergraduate Education Committee of ASM

One of the outcomes of the Undergraduate Education Conference 2000 was a set of curriculum guidelines for students majoring in microbiology and other fields (allied health, biotechnology, biology, and non biology majors). Summaries of each working group's recommendations are forth coming. We plan to revisit this topic at the upcoming Undergraduate Conference in Orlando and feel it is important to summarize the recommendations proposed for microbiology majors, as this group generated the most discussion. A goal of the next Undergraduate Conference is to finalize the recommendations.

Three working groups met to discuss curriculum recommendations for microbiology majors. By and large their proposals were the same so I have attempted to provide a summary that reflects the views of the groups. Each group developed a list of core courses (those to be taken by all in the major), elective courses (those chosen by individual students, depending on their interests and career goals), and supportive courses (those that provide fundamental knowledge required for taking microbiology courses). The list of courses presented in the three boxes assumes a semester-based academic calendar.

The list of core courses (Box 1) is composed of courses recommended by all three groups. It was also suggested that each core course include laboratories. The list of elective courses (Box 2) includes courses placed in this category by all three groups, as well as some courses that were included in the core list by one or two groups, but not by all three. Immunology and pathogenic microbiology were the most controversial. All groups listed them as courses that should be offered but inclusion in the core was not unanimous. Box 3 shows the supportive courses suggested by the groups.

In addition, the groups also developed a list of skills thought to be important for the microbiology major. These include general research skills (e.g., microscopy, media preparation, anaerobic technique, use of diagnostics), communication skills (both oral and written), and computing skills (from the basics of word processing and electronic presentation to use of spread sheets and bioinformatics).

Clearly these lists are only the starting points for discussion. For instance, one of the major problems noted was lack of time and resources. The lists are long. How does one fit these courses into a 4-year program? Additional discussion on timing of courses is also needed. For example, is it necessary to complete organic chemistry before taking Introduction to Microbiology? Is there a logical sequence of courses? Is there another way to accomplish the same goals by offering courses that integrate these topics? The concept of tracking students with different interests was noted. Is this a good idea or should we train students more broadly?

Another issue is the recommendation that the core courses all have labs. This is an appropriate recommendation, but it is expensive. How do departments with limited resources deal with this problem? Rather than offer a lab with every course, might it be better to

Box 1. Core courses for microbiology majors

- Introduction to
- Microbial Physiology
- Microbial Genetics
- Microbial Diversity and Ecology
- Capstone course (e.g., senior seminar presentation, independent research project, internship)

Box 2. Elective courses for microbiology majors

- Immunology
- Pathogenic Microbiology
- Food and Dairy Microbiology
- Soil and Aquatic Microbiology
- Industrial and Applied Microbiology
- Virology
- Parasitology/Protozoology
- Mycology
- Phycology
- Epidemiology
- Public Health
- Undergraduate research and internship

Box 3. Support courses for microbiology majors

- General Biology
- General Chemistry
- Organic Chemistry
- Biochemistry
- Math (level not specified)
- Physics
- Statistics
- Scientific Writing and Technical Communication

offer a two-semester sequence of independent lab courses that teach the skills needed to be a microbiologist?

One of the goals of the 2001 Undergraduate Education Conference will be to finalize the recommendations for a microbiology major curriculum. ASM is the first place contacted for such information when programs are reviewing their curricula or are undergoing major department reviews. I know that as a member of a department currently in the process of redefining the curriculum for majors, such information is invaluable. It is essential that ASM formulate guidelines that are agreed upon by the majority of microbiology educators. Please review the results of last year's discussion and comment directly to me (Baker.2@osu.edu) so I can incorporate your ideas into the material to be discussed at the next meeting. If I missed anything from your group discussion that you feel needs to be included, please contact me and I will include it for discussion at the meeting.

MicrobeLibrary.org

The MicrobeLibrary is a peer-reviewed, web-based collection of resources for teaching microbiology. The Library builds upon the scientific expertise, intellectual creativity, and private collections of the 42,000 members of the ASM.

Anyone who has developed innovative classroom and laboratory exercises or who has created images, animations, video clips, or other materials depicting the microbial world which can be used for teaching undergraduate microbiology should consider submitting them for inclusion in the MicrobeLibrary.

Submissions are accepted continuously.

Deadline for next review is July 1st.

Submission instructions and review criteria are available at http://www.microbelibrary.org/Submissions/frame7.htm

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E-mail: MicrobeLibrary@asmusa.org
http://www.microbelibrary.org/Journal/page4.htm

JOURNAL WATCH

If you have recently published an article or if you have recently read an article you found interesting, please contact Linda Sherwood at lsherwood@montana.edu *so that we can share it with others.*

Use of a Digital Camera to Document Student Observations in a Microbiology Laboratory Class by David A. Mills, Kevin Kelley, and Michael Jones. *The American Biology Teacher* 63:119.

Fun Microbiology: making Quick Soft Pretzels using a Variety of Flours by James K. Mitchell and Melissa A. Warden. *The American Biology Teacher* 63:50.

A Test of Hypotheses about Random Mutation: Using Classic Experiments to Teach Experimental Design by Donna M. Bozzone. *The American Biology Teacher* 63:54.

The Original Biotechnology: Brewing an Undergraduate Education by D. Waechter-Brulla and M. Woller. *Journal of Industrial Microbiology and Biotechnology* 24:327-333.

Microbiology in Lilts and Rhymes
(From the 1660s to The Golden Age)

Nelliah Hariharan
WOCKHARDT Research Center
Aurangabad, India

There was an Englishman, **Robert Hooke**
Through slices of cork, who loved to look.
And amidst his peerings, the world he tells,
"Look here, fellowmen, these are *Cells*." ***1665***

A curious, pious, and quirky bloke,
A Dutchman, by name **van Leeuwenhoek**,
Ground exquisite lenses all his life ***1676***
To Man, revealed new forms of Life. ***–1723***

Then from the people a question was given,
From where, indeed, has Life arisen?
And those that answered, sang in chorus,
"From lifeless things, of course, of course!"

Against this, the Italian, **Redi**
Furnished a proof, simple and ready;
That maggots in meat do not breed
Sans their eggs, their natural seed. ***1670s***

But said the many, with upturned noses,
"This is all fine with flies and roaches,
But animalcules can surely arise,
All by themselves, and in a trice!"

Then, there was a silence brief,
As **Spallanzani**, boiling broth of beef,
Shook the belief, deep and rife
That Life need not be born of Life. ***1767***

When French wineries were in real ferment
Compounding many a brewer's torment,
'Twas **Pasteur**, who came to the salvage
Of vats of wine, from habitual spoilage. ***1857***

But his mission was far from finished
For, waited the triumph he most relished,
When once for all he struck dead
Spontaneous Generation rearing its head. ***1864***

In a hamlet of *Deutschland*, little known;
Labored a physician, quiet and alone.
Fighting a formidable, invisible battle
To save the lives of sheep and cattle.

He stopped the pestilence in its tracks,
The bane of cattle, the fatal Anthrax;
Soon, the world to his greatness awoke,
The genius, that was of **Robert Koch**. ***1876***

Those times witnessed a Europe overrun
By Tuberculosis, a murderous demon!
But **Koch**, of methods brilliant and subtle,
Pinioned fast the bacillus "tubercle". ***1882***

Metchnikoff of the land of the *Czar*,
The *protegé* of **Pasteur** *excellence par*,
Studied the ways of the Phagocyte,
On the body's defenses, shed new light. ***1884***

At last, on the trail of the rabid dog,
With zeal and excitement all agog,
Sped **Pasteur**, the fighter of disease;
For mankind, conquered the dreaded Rabies. ***1885***

In the African jungles, far from home,
Stalking the treacherous Trypanosome,
Battled the Englishman, **David Bruce**,
With Sleeping Sickness, without a truce. ***1898***

Paul Ehrlich, a German and a chemist,
Hunting the germ with the corkscrew twist,
From Syphilis, vowed to rescue Man,
With his "magic bullet" *Salvarsan*. ***1910***

Diphtheria, Pox and the deadly Plague,
For mankind now are memories vague.
Reed and **Smith** and **Ross** and **Behring**
The string of heroes is truly unending!

Today, the science stands proud and tall,
A tribute to men who gave their ALL,
To answer mankind's distress calls,
Themselves, hazarding perilous falls!