6

Through the use of project-driven student teamwork and research, faculty can involve students in active communities of learners.

Teamwork and Research at the Frontiers of Learning

Robert Yuan, Spencer Benson

This chapter describes a pedagogical approach in which students learn through working on research and projects in teams. Carefully facilitated by faculty, student teams can become small intellectual communities. Though this educational approach was originally designed for teaching courses in the biological sciences, it can easily be applied to other disciplines. Even for students who reside on campus, there are limited opportunities for forming groups centered around academic tasks and intellectual activities. For commuter students, forming such groups is significantly more difficult.

Conceptual Framework

The teamwork and research approach is based on three related concepts: the virtual workplace, journey without maps, and relevance and understanding. The implementation of these three concepts enables the creation of communities of learners that offer multiple benefits to student participants regardless of their residential status.

The Virtual Workplace. The virtual workplace concept requires students to develop both their understanding of basic biology and fundamental career skills as they proceed from introductory to senior-level courses. These critical career skills include acquiring and processing information, integrating information and knowledge from several disciplines, using science in different contexts, working effectively in teams, participating in peer

This work has been supported in part by grant DUE9752324 from the National Science Foundation.

review, and effectively communicating in multiple media (Center for Science, Mathematics, and Engineering Education, 1996; Benson and Yuan, 1998). Students are encouraged to read scientific papers; access databases and the Internet; obtain information from specialized libraries; and contact experts by telephone, e-mail, and fax. This virtual workplace experience mimics what students will do in postgraduate career positions.

Journey Without Maps. Journey without maps represents an effort to encourage students from heterogeneous backgrounds to work together effectively as a team on tasks that are often interdisciplinary and cross-cultural (Yuan and Benson, 1998). It combines increased student-to-student communication, the use of intentionally mixed teams, the development of cross-cultural teaching materials, and the establishment of a set of interdisciplinary and cross-cultural courses. Its purpose is to go beyond the study of diversity by engaging students in the experience of diversity.

There is much evidence that learning occurs when individuals are intrinsically tied to others as social beings (Joint Task Force on Student Learning, 1998). Powerful and enduring learning seldom results from passively sitting in a traditional classroom. It is far more likely to occur when students are actively engaged in projects and is often enhanced when the projects involve diverse teams of students.

Students, particularly in a large university, usually associate with a rather small group of individuals from similar backgrounds and seldom even get to know, much less academically interact, with classmates outside their own circles. It is typical for students to not know the name of the students who sit beside them in a large lecture, even when they see each other at every class. Teamwork can help to counteract this common phenomenon. To encourage interaction and to capitalize on the diversity present in classes, teams are routinely selected by the instructor and are mixed by race and ethnicity, gender, cumulative grade point average, performance in prerequisite courses, and academic major. Because team projects account for a significant portion (30 to 60 percent) of the course grade and because a percentage of the project points are based on peer evaluations, individuals are encouraged to move beyond personal differences to achieve success in group projects. For commuter students in particular, the creation of a team of learners can be significantly enhanced by technology. Chapter Eight describes various ways in which technology can enable teamwork among students who are separated in time and space.

It should be noted that all teams do not work equally well together and that all team products are not above average in quality. On average, 10 to 20 percent of instructor-selected, mixed teams have difficulty in establishing a productive community. Most of these groups are able to work out their problems if not offered an easy out by the instructor. In a few cases, groups are irreversibly dysfunctional and must be restructured.

Relevance and Understanding. The concept of relevance and understanding is especially useful in working with commuter students who often find it hard to build connections between their academic courses and the

social structures of the academic community on one hand and the off-campus environments in which they live and often work on the other. There are a number of ways in which relevance to the workplace and the larger society can be integrated into courses to make them more meaningful to many commuter students who complain of a disconnection between their on- and off-campus worlds.

Relevance of courses at the personal level can be introduced in a simple manner. For example, in courses taught by the authors at the University of Maryland such as Microbes and Society, General Microbiology, and Principles of Biology, part of the final assessment is an essay in which students are asked to describe their major, their career plans, and their most serious interests or experiences. They then select a topic that has been covered during the semester, give an overview of the scientific concepts, and explain how these concepts relate to their aspirations, interests, or experiences. One student whose mother had undergone treatment for breast cancer examined lifestyle factors that could have influenced the onset of the disease. A history major described how armies suffered more casualties from infections than from combat until well into the twentieth century. An English major who delighted in writing science fiction wrote a short story in which gene therapy was used to engineer more intelligent human beings. This exercise enables students to build meaningful connections between their everyday existence and their academic pursuits.

Using the team approach to connect course concepts to broader social concerns has also produced positive results. Student teams in General Microbiology write review articles using the *New York Times* science section as a model. The article topics are based on the lectures. In such an exercise, students not only have to understand the science but must also make it relevant to a general readership that may only be marginally science literate. Microbial Ecology student teams develop a Web site addressing issues of social concern, such as biological warfare, bioremediation of pesticides, or biodegradable microbial plastics. As with the other pedagogical approaches, when students perceive a linkage between academic exercises and the world beyond academia, they are more motivated, retain more of what they learn, and build other connections between the classroom and their present and future lives.

These approaches have been employed by the authors in nine courses that span the spectrum of course types. Five courses are required or elective for students majoring in the biological sciences with a specialization in microbiology and include both upper- and lower-level courses. The remaining courses serve nonbiological science majors. Some of them are interdisciplinary, such as To Stem the Flow: The Nile, Technology, Politics, and the Environment (known as "the Nile course"), and are general education courses that combine aspects of biology, engineering, and political science. Two of them are honors courses in which students develop interdisciplinary projects that combine biology or biotechnology, medicine, economic development, and culture. The sizes of the classes vary from small groups of less

than 20 in the honors courses to large lecture-lab combination courses in General Biology and General Microbiology consisting of 200 to 400 students.

Courses Based on Student Teams

The concepts described earlier can be applied to the use of student teams in a wide range of courses. This section profiles three different types of courses in which the authors have employed them.

The Diversity Notebook is a curricular approach that has as its objective the development of cross-cultural course material in case-study format. Scientific concepts taught in most biology courses in the United States may be universal, but the examples used to illustrate them are drawn almost totally from the U.S. experience. The Diversity Notebook is a collection of case studies that provide culturally diverse examples of the application of basic scientific concepts in different regions of the world. It has been designed to achieve the following course outcomes:

- To highlight the relevance of science and its applications in different cultural contexts
- To expand students' awareness of other cultures
- To encourage students to take a more global and holistic view of science
- To familiarize students with the idea of *appropriate technology,* defined as the choice of a product or process that fulfills a specific need in a manner that is suitable for a particular cultural and economic environment

The Diversity Notebook provides an opportunity for students in Biology in a Cultural Context, an honors seminar course, to participate in the creation and recording of knowledge. Student teams including nonscience majors define a scientific problem that illustrates a basic concept; evaluate possible solutions; and explore the economic, social, and cultural implications of such solutions. The end product is a student-generated case study for the Diversity Notebook. The seminar demonstrates that the development and use of interdisciplinary and cross-cultural case studies does not dilute science content or learning. In fact, it stimulates deeper learning of science because students must conduct research and develop their cases and, at the same time, focus on the relevance of science to society.

A second example of use of student teams is a sophomore-level honors course, Biotechnology in Asia. This course examines technology, economic development, and culture in four countries that illustrate different levels of development: Japan, Singapore, South Korea, and China. The students work together in country teams, each of which becomes an expert panel on the given country by the end of the semester. The teams are responsible for cable reports (the standard form of communication between U.S. embassies, the U.S. State Department, and other governments) on specific aspects of biotechnology in their country, final country reports, and oral briefings

based on the written reports. These reports require brevity, clarity, and objectivity, with the intention that any individual reading it anywhere in the world will get the same unambiguous message.

The topics that students select focus on industrial and agricultural development, public health, and the environment. Students learn how a particular technology can be seriously affected by economic factors, such as when South Korean pharmaceutical companies develop vaccines as a way to enter the global drug market, or cultural ones, such as how genetic engineering of rice in Japan has as much to do with the central role of rice in the culture as it does with food production. At another level, students observe that four countries with Confucian cultures have developed approaches to economic development that are different from those with non-Confucian cultures. Students come to understand how high technology, economics, and culture intersect in these Asian countries.

World courses are lecture-discussion courses designed to introduce students to interdisciplinary thinking. Unlike the honors seminars, these are large-enrollment courses open to all students and include first-year students as well as graduating seniors. These unique courses, which satisfy general education requirements, are developed and taught by teams of faculty and graduate assistants from different departments and colleges. They focus on important issues, such as technology and the environment, or intellectual concepts, such as creativity. In the Nile course, for example, students examine the topics of technology, politics, and the environment through the lenses of history, politics, engineering, and biology. The course includes a team project in which student teams use a Nile basin simulator to simulate changes in the water distribution of the Nile River and then assess the impacts on the agriculture, hydrology, biology, and politics of Egypt. The team projects include a written report on the cost-benefit ratio of particular impacts and an oral presentation. For both the written report and the presentation, students must identify individual team-member strengths and then decide how to best use these strengths to achieve their purpose.

Learning Through Research

Hands-on laboratory research with a faculty mentor is one of the most stimulating undergraduate educational experiences. However, space, resources, and staffing limit such research opportunities to a small percentage of students. It is nevertheless possible to introduce students to research through a process in which they collect, read, and analyze primary and review literature as the basis for developing research proposals.

In Microbial Physiology, a large lecture-discussion course, students prepare four research proposals. In the first three, they read reviews of major course topics and use the information to develop an abbreviated research proposal that consists of an introduction, objectives, an experimental approach, and a conclusion as well as tables, figures, and references. In the

final assignment, the students are given the prospectus for a biotechnology company and asked to develop the executive summary for a business plan that includes scientific background, a research and development plan, market analysis, business strategy, risks and risk management, and a conclusion. This last assignment requires that students apply knowledge and skills acquired from the first assignments to a different task. In addition to the written proposals, each student team makes an oral presentation. This is similar to the approach used in the honors courses described in the preceding section, except that the products in the honors courses are case studies and country reports rather than a business plan. In the Microbial Ecology capstone course, student teams develop two case studies, one on a bacterial species and the second on a technology concept such as microbial-based plastics. In this course, the deliverables are Web sites that are reviewed by members of the class and peer-evaluated oral presentations.

A similar pedagogy can be applied to laboratory courses. For example, students in the first three course modules of Microbial Genetics are provided with the objectives of experiments as well as the necessary reagents and equipment. They are then required to design the actual experimental protocols. These protocols are reviewed and graded by the teaching assistants and instructor before the students perform the experiments. In the final course module, each student team designs and carries out a research project. This module concludes with an oral progress report and a final written report in the format of a scientific paper.

Student and Course Evaluation

The establishment of a community of learners through a team experience requires a sense of responsibility to the team and to the standards of academic excellence set by the instructor. In the upper-level and honors courses described in this chapter, research proposals, reports, case studies, Web sites, and oral presentations are subject to peer review by fellow team members. In each course, team members review each other's work based on level of effort and productivity. In the Microbial Ecology course, for example, peer review accounts for 10 percent of the course points. The team peer evaluation allows for the conversion of a group grade to an individual grade based on an individual's contribution to the team. Students are sharply cognizant that poor participation not only affects team performance but also ultimately affects their own grades. The instructor provides timely feedback on written reports, case studies, Web sites, and oral presentations. Informal discussions occur between student and instructor both in person and via e-mail. In addition, students do extensive course evaluations. These evaluations provide the instructor with students' views on the amount of effort required for the various tasks, the perceived value of each task, progress made, overall assessment of the course, and suggestions for course modifications. An oral town-meeting-type evaluation is also routinely conducted by the instructor.

Conclusion

In *Realizing the Potential of American Higher Education,* the Study Group on the Conditions of Excellence in American Higher Education (1984) pointed out that there are three critical conditions for excellence in learning: student involvement, high expectations, and assessment and feedback. By involving undergraduates in teamwork and research, it is possible to develop and implement a comprehensive strategy to create communities of learners that meet these conditions. Whether they do research conceptually or hands-on in the laboratory, students learn a great deal when they experience the adventure of research and the satisfaction of contributing to the success of a team. As students learn collaboratively, they are able to teach their peers. Students who become experts in specific areas are able to enjoy the satisfaction of teaching their instructors as well.

In the approach described in this chapter, tasks are deliberately constructed so that high levels of achievement can be reached only by team effort. The brightest students are thus empowered to invest effort in enabling their peers to reach their full potential. For the others, the ability to contribute to a high-quality project with the encouragement of their peers brings unique rewards. Learning is stimulated by constant peer review and accountability. Students come to recognize clearly that the ability to work in diverse groups is necessary for success. Despite the initial discomfort of some students as they approach new tasks and realize that their success depends heavily on others, students report a deep sense of satisfaction in being able to accomplish their tasks and to do so in the context of the team.

References

Benson, S. A., and Yuan R. T. "The University Classroom as a Virtual Workplace." In S. Selden (ed.), *Essays in Quality Learning: Teachers' Reflections on Classroom Practice.* College Park: University of Maryland, 1998.

Center for Science, Mathematics, and Engineering Education. *From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology: Report of a Convocation.* Washington, D.C.: National Academy Press, 1996.

Joint Task Force for Student Learning. *Powerful Partnerships: A Shared Responsibility for Learning.* Washington, D.C.: American Association for Higher Education, American College Personnel Association, National Association of Student Personnel Administrators, 1998.

Study Group on the Conditions of Excellence in American Higher Education. *Involvement in Learning: Realizing the Potential of American Higher Education.* Washington, D.C.: U.S. Department of Education, 1984.

Yuan R. T., and Benson, S. A. "A Journey Without Maps." In S. Selden (ed.), *Essays in Quality: Learning: Teachers' Reflections on Classroom Practice.* College Park: University of Maryland, 1998.

ROBERT YUAN is professor and of cell biology and molecular genetics at the University of Maryland.

SPENCER BENSON is associate professor of cell biology and molecular genetics at the University of Maryland.