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The virtual workplace: integration of research approaches and fundamental skills into an upper level biology course

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Undergraduate science education is based on a model developed in the decade following World War II. It has undergone no fundamental changes since then with courses that combine lectures and laboratory experiments. Traditional courses are typically based on individual performance and much of that performance is evaluated by tests and examinations. At the same time, the modern workplace has undergone revolutionary changes that are characterized by: interdisciplinary approaches; work in teams; the exponential growth of scientific information; the rapid turnover in projects; the need for continued retraining; multiple career tracks; the globalization of science and industry; and the pervasive use of electronic communications and information systems. *Journal of Industrial Microbiology & Biotechnology* (2000) **24,** 310–313.

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An important element in the biological sciences is the preponderance of new jobs in the industrial sector which requires the ability to function in the work environment described above. This has resulted in a growing effort to restructure undergraduate science education [6,9,10]. This movement has benefited from many of the ideas in active and cooperative learning [1,3,4,7] that have been translated into the science classroom [12,13].

This article describes the structure and activities of a microbial physiology course. This is an upper-level lecture course that has a maximum enrollment of 32 students, most of whom are seniors with a number of juniors. Normally, about half the students are microbiology majors with the remainder coming from other disciplines such as biochemistry, physiology, and engineering. The revision of this course is in the context of a serious effort to transform a set of eight courses in the Microbiology curriculum. We have entitled this curriculum concept, 'the Virtual Workplace,' [2] and intend it to provide students with a spectrum of thought processes and skills that prepares them for a variety of scientific and science-based careers.

Basic concepts and in-depth active learning

The microbial physiology course is designed to integrate a series of lectures that cover the principal concepts in this field (eg, cell biology of bacteria, basic metabolism, chemotaxis) with a series of tasks that combine research with analytical and communication skills. Since most of the students have had one semester of biochemistry and may be taking their second semester of biochemistry concurrently, they are familiar with the biochemical reactions and pathways that provide the background for such a course. Much of this material is presented in the context of the needs of the cell and its regulatory mechanisms. The last lecture is dedicated to a presentation and discussion of current scientific trends, the characteristics of the job market and career tracks. Their mastery of the course knowledge is tested in one midterm and one final examination. While these tests provide a measure of student learning, they are equally important in providing students with a sense of security. Examinations have been a routine aspect of their course work while the other tasks in this course are definitely not.

Interspersed throughout the course are four major assignments that are linked to major course topics (Table 1) and provide the basis for in-depth active learning. In three of the assignments, the students are assigned to prepare abbreviated research proposals on selected topics. The fourth assignment is of a totally different nature (see below). Students can choose two different scenarios: a university grant proposal or a proposal in a pharmaceutical company. For each project, they are given a minireview. This along with the course lectures provides the starting point for the proposal which is four pages in length. It includes an introduction, objectives, experimental approach, expected results and conclusion. Unlike similar assignments in my graduate course, it does not include experimental details, budget and staffing.

Students improve their skills through the semester. The fourth assignment is fundamentally different from the preceding ones, forcing the students to adapt what they have

Table 1 Course assignments

Assignment	Nature of assignment	Topic
1	Research proposal	Cell wall synthesis
2	Research proposal	Transport mechanism
3	Research proposal	Conjugation
4	Evaluation of business plan	Anti-sense technology

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learned to a novel task. They are provided with a real prospectus for a biotechnology company that is making a public offering. Most of the information relates to the technology and its applications. A substantive component is an analysis of the potential market, risks, regulatory and intellectual property issues, existing competitors, and projected revenues and capital requirements. The students play the roles of the corporate team writing an executive summary to seek financing from a state pension plan. The object of this exercise is to combine scientific information, business opportunity, and risks and returns. Table 1 summarizes the four proposals. A student from each team gives an oral presentation of the research proposal (or reviews a proposal—see below). The abbreviated format used in the written assignments is appropriate to the educational level of the students. Importantly, it also enables the students to learn how to research and conceptualize proposals on totally different subjects.

Fundamental skills

While analytical and communication skills are considered to be essential for a scientific career, they are seldom taught in the context of a science course. These are built into this microbial physiology course.

Computer skills

All students are required to have an university computer account and to subscribe to the course ListServ. Their first task is to post a one-page biography on the ListServ (as does the instructor) so that all the participants in the course can familiarize themselves with each other. This is particularly useful in a large campus where many students are commuters. E-mail is an important tool for team members to communicate with each other and with the instructor as they put their projects together. The Web is an important source of information for the research proposals and many students make use of computer graphics for their proposals and presentations.

Teamwork

Students are assigned to teams by the instructor. Teams are deliberately mixed by gpa, performance in course prerequisites, major, race/ethnicity and gender. An essential element for the success of the teams is that the tasks are complex and held to high standards. This makes it difficult for one or two individuals to do all of the work. Since students have different backgrounds and skills, their contributions to the task will vary. The achievement of the individual is dependent on the performance of the team. Each individual is also subject to peer review by the other members of his/her team.

Professional writing

Though students do an increasing amount of writing in their courses, they rarely have the opportunity to write in a professional context. As indicated in the preceding section, the preparation of a research proposal requires substantial research, consideration of different experimental approaches and preparation of a clear and concise document with supporting tables and figures. Grading is based not only on content, but also on the quality of the writing and the format of the paper.

Oral presentations

In their future careers, students will not only need to write papers and proposals, but will also be required to make oral presentations. In this course, they will be required to make one 15-min presentation (including questions from the audience) to the class. They have their choice of presenting their team proposal or of reviewing the proposal from another team. The presentations are strictly timed and the use of overhead projections and computer graphics is encouraged. The instructor provides a written critique of each presentation.

Peer review

This is one of the fundamental aspects of modern science. Peer review is built into the course at three different levels. Informally, students will ask questions and make critical comments during the oral presentations. Those students who have chosen to be reviewers will receive a research proposal for their examination and will take careful notes during the corresponding presentation. It is their responsibility then to review the proposal based both on the written document and the oral presentation. Finally, at the end of the semester students have to evaluate the efforts of their team mates on the basis of level of effort (40% of group grade) and productivity (60% of group grade). This peer evaluation is then used to convert the group grades into individual grades. While most students are generous with their peers, they are strict with those whom they consider to have evaded their responsibilities. A low peer evaluation can result in a decrease of a full grade.

The grading of the course is designed to balance individual and group activities as well as measure the various skills.

Midterm exam: 15 points
Final exam: 25 points
Assigned team projects: 4×10 points = 40 points
Oral presentation: 20 points

The course has a total of 110 points which compensates for lower performances in the first two team projects.

Evaluation of the course

This course has now been taught for five semesters with some minor changes. Its effectiveness depends on how well students can integrate critical reading and thinking with those fundamental skills that are necessary in a scientific career. At the end of the semester, the course is evaluated using methods developed in collaboration with the university's Center for Teaching Excellence.

One initial concern was the difficulty of the work load and the possibility that this might negatively affect students' grades. Table 2 summarizes the grades for five semesters. They indicate that the students' performance is not worse than in a standard course and if anything they seem to do somewhat better (A's and B's making more than half of the grades). During a semester when the instructor was

Table 2 Final grade distribution

Grades	1994	1995	1996	1997	1999
A	36%	26%	25%	26%	42%
B	16%	30%	30%	39%	26%
C	16%	35%	30%	9%	16%
D	12%	9%	10%	13%	19%
F	20%	0	5%	13%	0%
n	19	23	20	23	19

on sabbatical and was replaced by a faculty member who taught the course in a modified manner (two exams, one oral presentation and one paper), the grades were A: 38%; B: 38%; C: 13%; F: 13% ($n = 24$). A second important issue is whether there is any evidence that the students make any progress in the research proposals throughout the semester. Table 3 summarizes team grades for the four assignments during a semester. They show that four of the five teams improved during the semester while one team remained at about the same level. The results for two other semesters show a similar pattern: (a) three teams improved, one remained the same, and two decreased; (b) four teams improved and one remained the same. It is also important to note that this improved performance occurred even when the last assignment involved a task (preparing an abbreviated business plan) that is different from the preceding three assignments.

Such data suggest that most students are able to work effectively as a team and learn how to read primary sources critically and develop a research proposal (which requires competence in both written and oral skills). Following the final examination, students are asked to complete a detailed evaluation form (for which they receive five points in the final examination). Table 4 provides a typical set of student evaluations. These evaluations are a good indicator that the course has been effective in providing the students with the experiences for which it had been designed.

Objectively, there are two ways in which teamwork can be assessed: peer evaluation of team members and team grades given by the instructor. If individuals get low peer rating (ie, below 75%) and their team grades do not improve or drop as they proceed through their four assignments, these are clear indicators of dysfunctional groups. Over various semesters, two to four students received poor ratings from their team mates and possibly one team had problems adjusting. Such a cost is bearable given the benefits to the class as a whole. In our view, the positive results using team work are based on the methods used in this course: it is mandatory, the tasks are difficult and complex (and thus not easy for one or two individuals to handle on their own) and all of the students know from the outset that they will be reviewed by their team mates.

Table 3 Assignment grades (1995, $n = 23$)

Team	Assignment No. 1	Assignment No. 2	Assignment No. 3	Assignment No. 4
1	7.0	7.3	8.8	7.0
2	8.0	8.0	9.0	9.5
3	8.0	9.2	9.2	9.0
4	7.5	7.8	8.5	8.7
5	8.5	7.5	9.0	9.5

Maximum grade = 10.0.

Table 4 Course evaluation ($n = 23$)

- The assigned mini-reviews were somewhat difficult: 17 (74%)
- The research proposals were somewhat difficult: 17 (74%)
- The research proposals are an important part of the course: 20 (87%)
- They learn from preparing research proposals: a critical attitude 11 (48%)
  Experimental design: 9 (39%)
  Team organization: 5 (22%)
- Working in teams: important to learn how to do it: 18 (78%)
  difficult to do: 11 (48%)
- Oral presentations are somewhat difficult: 10 (43%)
- Oral presentations are an important part of the course: 20 (87%)
- Peer review is a useful part of the course: 20 (87%)
- The course was worthwhile and you would recommend it to other students: 22 (96%)

Conclusion

The overall goal of this course is to provide students with an approximation of what will be required of them in gradu-

Table 5 Student comments

On research proposals

- I think these proposals allowed some of us to practice ideas that we learned in other courses such as recombinant DNA technology.
- They were very helpful. I enjoyed them. Good experience.
- It was very appropriate to what we have been learning and shows us a part of job required if someone was actually doing this in real life.
- I hated them while I was doing it, but now that it's over, I'm glad for the experience. I showed one of the proposals on a job interview and I was hired!

On teams:

- Group interaction is a good idea because it would have been hard for one person to work alone with some of the proposal.
- I generally don't like it, but I had an outstanding team. We worked together well and I have enjoyed it.

On oral presentations

- One has to explain one's thoughts to one's peers. Presentation is critical.
- Discipline. Public speaking. Don't fidget around. Look good and professional. Care about what you're talking about.
- The oral presentations relate to our futures as scientists and being able to discuss our findings.

Best aspect of the course:

- Proposals, learning concepts rather than memorizing facts and figures.
- The real world experience brought to the course.
- Research proposal and presentations.

ate school and in the workplace. The content aspect of the course combined an overview of metabolism and regulation in bacterial cells with an in-depth research in the selected project areas. Teamwork is an inherent feature of the research proposals as are communication skills. Teamwork combined with peer review is a major driving force in the course [5,8,11]. Such an approach can be equally applied to other courses in the biological sciences. This is the approach that we have taken in other courses. Student comments have been generally favorable (Table 5) and enrollment in such courses has remained stable or increased over the years, providing a measure of the value that students see in such courses.

A course like this requires more effort from both faculty and students. This is justified in that students perceive that what they are doing is relevant to the real world. They also learn (very often for the first time) that course material is only the launchpad for a lifetime of continuing learning. The process of working in teams and of reviewing and revising their work leads to learning from their peers [12]. While a student often expects an instructor to be both knowledgeable and expert in the field, he/she is likely to take a criticism more seriously when it comes from someone at their level. The instructor also becomes a fellow learner since he/she cannot be familiar with all details of their proposal. In the end, the students discover that learning has many sources and is a continuing process linked to real life and one for which they are ultimately responsible.

References

1 American Association for Higher Education. 1998. Powerful Partnerships. A Shared Responsibility for Learning. American Association for Higher Education, Washington, DC.
2 Benson SA and RT Yuan. 1998. The university classroom as a virtual workplace. In: Essays in Quality Learning (S Selden, AA Assad and JD Greenberg, eds), University of Maryland, College Park.
3 Bonwell CC and JA Eison. 1991. Active Learning: Creative Excitement in the Classroom. ASHE-ERIC Higher Education Report No. 1. George Washington University, Washington, DC.
4 Brufee K. 1993. Collaborative Learning: Higher Education, Interdependence and the Authority of Knowledge. The Johns Hopkins University Press, Baltimore, MD.
5 Davidson N. 1998. Small-group cooperative learning: what I have learned in the past thirty years. In: Essays on Quality Learning (S Selden, AA Assad and JD Greenberg, eds), University of Maryland, College Park.
6 Holden C. 1989. Radical reform for science education. Science 243: 1133.
7 Johnson DW and RT Johnson. 1987. Learning Together and Alone: Cooperative, Competitive and Individualistic Learning. Prentice Hall, Englewood Cliffs, NJ.
8 Millis B and P Cottell. 1998. Cooperative Learning for Higher Education Faculty. Oryx Press, Phoenix, AZ.
9 National Research Council. 1996. From Analysis to Action: Undergraduate Education in Science, Math and Technology. Report of a Convocation. National Academy Press, Washington, DC.
10 Project Kaleidoscope. 1991. What Works: Building Natural Science Communities, Vol 1. Stamats Communications, Washington, DC.
11 Sharan Y and S Sharan. 1992. Expanding Cooperative Learning Through Group Investigation. Teachers College Press, New York, NY.
12 Tobias S. 1992. Revitalizing Undergraduate Science, pp 114–122. Research Corporation Tucson, AZ.
13 Uno GE. 1990. Inquiry in the classroom. Bioscience 40: 841–843.