Training in "Multidisciplinarianism"

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Abstract

Cross-functional and multidisciplinary teams are increasingly common in business and the marketplace. Industry has migrated from a parochial view of disciplines to a broader view of teamwork as an effective means of increasing the creative capacity of the organization. As a reflection of this industrial need, the ABET Engineering Criteria 2000 (EC 2000) require that graduates of our engineering programs must be able to function on multidisciplinary teams (criterion 3(d)). Most existing educational programs provide little training for undergraduates in the skills necessary to function effectively on such teams. In our new "Multidisciplinary Bioprocessing Laboratory" (MBL) course, we have developed formal training exercises and intensive laboratory experiences that help our students develop multidisciplinary team skills. While the MBL course is focused on biocatalysis, the concepts and approaches used for instruction and training are generic and may be applied to a variety of interdisciplinary technology areas. We will discuss the course structure and give examples of exercises used in the classroom.

I. Introduction

"Employment Outlook 2000: Teamwork Pays Off." A recent issue of Chemical and Engineering News[1] featured this cover story on the need for multifunctional teams in the professional workforce. Regardless of the type of industry—whether it produces polyethylene or pharmaceuticals—many companies view the work accomplished by multidisciplinary teams as key to cutting costs, improving efficiency, and speeding products to market. Our paper describes the development and implementation of a Multidisciplinary Bioprocessing Laboratory (MBL) course in the Department of Chemical Engineering at Michigan State University that helps provide this type of training.

The development of interdisciplinary courses and curricula is not new; examples of notable efforts at Virginia Tech, University of Florida, Brigham Young University, and Rensselaer Polytechnic Institute are described by Ercolano[2]. Some of these courses are focused on projects (design or research) done by teams, and others educate students in interdisciplinary topics with no formal teamwork involved.

The development of our MBL course was motivated specifically by the increasing relevance of biotechnology research and production to the chemical industry[3]. This need was underscored by a panel of distinguished research chemists assembled by Chemical and Engineering News. The majority of the panel believed that chemistry applied to biology is one of the most intellectually stimulating of today's research frontiers[4]. Storck[5] also cites the importance of biotechnology for

U.S. economic competitiveness and the restructuring of several large chemical-manufacturing corporations to be more biologically based. Engineers play a vital role in speeding the delivery of products to the market. Their timely participation in multidisciplinary teams is especially important because the FDA requires elements of manufacturing processes to be "locked in" early in the development process; thus full participation of a multidisciplinary team is vital to achieving quick FDA approval.

Unfortunately, scientists and engineers, through differences in their academic backgrounds, do not naturally function together effectively on multidisciplinary teams.[6] Most engineering programs provide little training to prepare students for participation in such teams. Our objectives in developing the Multidisciplinary Bioprocessing Laboratory course were to answer this need on behalf of several of the most important constituencies of our program—our students, our graduates, and industry.

The development of this course was funded from the National Science Foundation (NSF) Combined Research-Curriculum Development (CRCD) Program and from industrial sponsors. Our expectation is that industrial support will allow us to continue this course offering beyond the duration of the grant. Our purpose was to develop the MBL course and the associated bioprocessing curricula to allow students to learn to work effectively in multidisciplinary teams in an industrially relevant context. The basic concept of providing formal training complemented by the testbed of an intensive laboratory experience in multidisciplinary teams is generic and could be applied to a variety of interdisciplinary technology areas.

II. Course Objectives

Just as in many land-grant institutions, the historic foundations for scholarly interdisciplinary collaboration at Michigan State University (MSU) have been strong, and the recent interactions with the life-sciences industry have been robust and active. The MSU Chemical Engineering Program also recently formalized a biochemical engineering option within its 128-credit curriculum. The academic infrastructure and industrial support were primed for the development of a multidisciplinary bioprocessing laboratory course.

In light of the needs of our industrial constituencies and the opportunities provided within our academic community, the MBL course learning objectives were developed to enable the student to:

- function effectively in a multidisciplinary team;
- solve a biotechnological research problem;
- conduct experiments in a multidisciplinary lab;
- be proficient in advanced research methods;
- exercise project management skills;
- communicate well in interdisciplinary settings; and
- efficiently use technical resources/databases.

The learning objectives were complemented by specific objectives for the course faculty and research mentors (described in the next section) that included:

- improvement of pedagogical skills in the instruction of multidisciplinary groups;
- integration of research into new educational laboratory projects;
- establishment of close research and educational interactions with each other and other project constituencies;
- putting into practice team- and project-based management of the course;
- becoming more proficient in understanding the connections between students' learning styles and their ability to perform creative work (research) in teams; and
- encouraging outstanding undergraduates to pursue graduate studies.

Both sets of objectives were implemented through a novel course structure, specific course content, mentor training workshops, and a comprehensive assessment process. This paper will focus on the methods for achieving the course learning objectives.

III. Course Structure

The course participants included the participating faculty, several research mentors, and the students. The *participating faculty* members are faculty with outstanding research program who provide laboratory research projects for the student teams. Each student team was assigned to a faculty lab in a discipline in which ideally none of the team members had expertise, i.e. the research area was in a discipline new to all team members. *Research mentors*, graduate students or post-doctoral assistants in the faculty members' labs, supervised the research projects.

The *student teams* were comprised of individuals representing different disciplines related to bioprocessing which have thus far included chemical engineering, microbiology, biochemistry, plant pathology, physiology, and chemistry. Only seniors or beginning graduate students were admitted into the course. This restriction was based on evidence provided by Aldridge[7] that truly cross-disciplinary learning occurs only when each team member can contribute to the assigned problem with his or her own disciplinary expertise. This, combined with the project focus on advanced laboratory research, dictated a minimum level of academic class standing in the students.

The first offering of the MBL course in the Spring of 1998 included eleven students representing six disciplines, six participating faculty, and four mentors. (This paper was submitted before the second offering. However, proposed course improvements will be described in the oral presentation.) It was offered as a three-credit course with a recitation hour and an expectation that the students would spend at least two 3-hour sessions in lab per week. Most teams spent considerably more time on their research projects.

The conceptual structure of the course is shown on Figure 1. The central "core" of the course is the weekly one-hour recitation section. During this hour the instructors of the course (the authors) provide the students with formal training in a variety of topics relevant to multidisciplinary teamwork. These topics are described in the following section. The students, who are divided into multidisciplinary teams early in the course, learn the basic skills in the core recitation session, and then have the opportunity to develop these team skills in the course's "outer core" by conducting interdisciplinary research projects in the laboratory portion of the course.

This course structure allows for the expansion of the course to include larger numbers of students by expanding the number of teams in the outer core. In this case, the material presented in the central core recitation section would remain common for all students. The course also features regular meetings between each team and the course instructors. These meetings allow for good interchange about the progress of the research and issues of concern, and are an excellent opportunity for formative assessment.

IV. Course Content

To support the team research being done in the labs, the material covered in the recitation session included training in multidisciplinary team skills, project management, creativity and problem-solving, communication skills, and the use of interdisciplinary library and database search tools. As much as possible, the material was presented in class on a "just-in-time" basis, so that the students would take what was learned in recitation and directly apply and further develop the appropriate skills as needed in their laboratory team research.

The research mentors were also provided with special training on teamwork skills in a several workshops that typically occurred before the course began. The mentors were introduced to such concepts as collaborative learning and team management, and were given guidelines (rubrics) by which to evaluate the students in their teams.

A brief description of the type of materials and classroom exercises that were covered in the recitation is given below:

- Multidisciplinary team skills. Various in-class exercises were used to develop an understanding of the team dynamics and the "language" of other disciplines. Specific approaches used were peer teaching, listening and interpretation exercises, peer teaching of research methods in the laboratory, and the use of the jigsaw method[7] for team problem solving.

  The "listening and interpretation" exercise was performed in the mode of the "telephone" game played by young children. In this activity, one student, the originator, describes a technical concept or technique germane to his/her discipline to another student from a different discipline. This student interprets and "passes on" the information to a third student of yet another discipline. The process is repeated as much as is reasonable for the class size and for the time available. The last student "retells" the information to the originator of the message. Finally, the entire class discusses the issues surrounding the interpretation and communication of technical information across disciplines.

- Project management. Recitation material covered the use of the Gantt and Pert chart methods, and student teams were required to apply these methods in early project and resource planning. Project management software was also made available to the students.

- Communication skills. Course requirements included both oral presentations and written reports. Particular emphasis was placed on minimizing use of discipline-specific jargon and/or using terminology appropriate for ones' audience. Teams were also required to write a project proposal early in the course. This required all team members to gain at least a minimal understanding of all multidisciplinary facets of their research projects. The regular meetings with the course instructors and with the research mentors allowed for opportunities to practice communication in a multidisciplinary setting. Team oral presentations were also valuable in keeping all students informed of work being done by the other teams in the class.

- Creativity and problem-solving. Discussions on these topics included developing an understanding of the unique strategies used by different disciplines for solving problems (scientists test a hypothesis while engineers design a process). An in-class team exercise focused on the development of an "on the spot" preliminary strategy for a hypothetical yet realistic research problem, which required teams to synthesize a research approach based on input from each discipline represented on the team.

- Library and database research. Students were instructed by MSU librarians on searching the literature outside of one's discipline. Although a fairly simple topic, students gave very positive feedback and found this to be most valuable in searching for background literature for their research projects.

In addition to the core material described above, another key feature of the recitation sections was the participation of industrial speakers. The three guests of Fall, 1998 gave presentations on various aspects of bioprocessing work in the industry including the containment of potent compounds, process validation procedures and FDA regulations, and the use of teams in the pharmaceutical industry.

In the first offering of the course, the students worked in laboratories in the fields of biochemistry, chemistry, microbiology, and plant pathology. For the purposes of illustrating the nature of the research projects, their topics and their "home" labs are listed below:
- Bioconversion of limonene to high-value terpenes (microbiology)
- Production of catechol by genetically modified plants (plant pathology)
- Production of protocatechuic acid using recombinant *E. coli* (chemistry)
- Protein engineering of thermostable alkaline phosphatase (biochemistry)

V. Strengths and Weaknesses

A comprehensive assessment program provided both formative and summative information on the progress and success of student learning in the MBL course. Throughout the semester, it was evident that the students most valued the opportunity to put into practice the team skills learned in the recitation section. This was viewed as an effective means of developing a multidisciplinary mindset and as being most useful in achieving this learning objective.

Secondly, the team members had mutual, very clearly identified project goals--another factor important to team success.[6] Additionally, the working and learning relationships between the teams and their mentors were a great strength of the program. Not only did the student teams learn from their mentors, but the mentors also became "students" of interdisciplinary collaboration and of cooperative learning.

Weaknesses of the program included the significant differences in the amount of time that students spent on project development. A few of the teams had very clearly defined projects and were able to begin to be productive early in the semester. Other teams worked on projects that were exploratory in nature with mixed success. It is clear that the prescription of research projects must be balanced among several factors. These include the students' potential for success in their projects, ample opportunity for development of creativity and problem-solving skills in the teams, and the cost/benefit ratio to the participating faculty member in the amount of research completed by the student.

Another potential weakness is the investment of faculty time in this type of course, particularly if a large number of students take the course. Ercolano2 has also cited this concern in his description of several interdisciplinary courses taught across the U.S. This is an issue that will be evaluated in future offerings of the MBL course.

VI. Conclusions

It is clear that several issues exist in offering courses in "multidisciplinarianism" such as those described both in this paper and by Ercolano. However, the need for individuals with training in multidisciplinary team skills is great both in academia and industry. The MBL course has shown preliminary successes in developing these skills. We anticipate that additional offerings of the MBL lab course with the associated assessment results will result in a class that is a staple of our curriculum and will make teamwork pay off both for our graduates and the faculty involved.

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Figure 1. MBL Course Structure