THE RESEARCH PROPOSAL
in Biochemical and Biological Engineering Courses

ROGER G. HARRISON, MATTHIAS U. NOLLERT, DAVID W. SCHMIDTKE, AND VASSILIOS I. SIKAVITSAS
University of Oklahoma • Norman, OK 73019-1004

The advancement of the U.S. economy is critically dependent on new developments in science and engineering technology. Undergraduate students in engineering are typically well trained in solving well-defined problems. They receive very little training past reading a textbook, however, in the creative activities involved in development of new technology.

One way to help students think creatively about developing new technology is to incorporate a research proposal into the coursework. Although numerous efforts have been made to incorporate more writing into engineering and science courses,[1-4] little has been reported about using research proposals in undergraduate courses. In an undergraduate course for chemistry majors at Brooklyn College entitled "Introduction to Research," students were required to select a research project provided by the instructor.[5] Students then wrote a rough draft of the proposal. After receiving feedback from the instructor, they wrote a final draft. In a Youngstown State University course entitled "Chemistry Research," students were required to select a research proposal topic, write a rough draft of the proposal, and then write a final draft after receiving feedback from the professor.[6] For both proposals, the time allotted for writing (five weeks at Brooklyn College and three weeks at Youngstown State) seems too short for undergraduates, given the challenging nature of writing a research proposal.

This paper presents our experiences incorporating a research proposal in four biochemical or biological engineering courses

Roger G. Harrison *is an associate professor in the School of Chemical, Biological, and Materials Engineering at the University of Oklahoma. His research focuses on the expression and purification of recombinant proteins, and the design of proteins for oncologic and cardiovascular applications. He is the lead author, with three coauthors, of the textbook* Bioseparations Science and Engineering *(Oxford University Press, 2003). He received his B.S. in chemical engineering from the University of Oklahoma and his M.S. and Ph.D. from the University of Wisconsin-Madison. After his Ph.D., he also worked in R&D at Upjohn Company and Phillips Petroleum Company.*

Matthias U. Nollert *is an associate professor in the School of Chemical, Biological, and Materials Engineering at the University of Oklahoma. His research in the area of biomedical engineering seeks to understand the role of fluid mechanics in modulating the biology of blood cells and the cells of the blood vessel wall. He received his B.S. in chemical engineering from the University of Virginia and his Ph.D. from Cornell University. He was a postdoctoral fellow at Rice University.*

David W. Schmidtke *is an assistant professor in the School of Chemical, Biological, and Materials Engineering at the University of Oklahoma. His research interests are in the areas of biosensors and cell adhesion. He received his B.S. in chemical engineering from the University of Wisconsin-Madison and his M.S. and Ph.D. from the University of Texas at Austin. He was a postdoctoral fellow at the University of Pennsylvania.*

Vassilios I. Sikavitsas *is an assistant professor in the School of Chemical, Biological, and Materials Engineering at the University of Oklahoma. His research interests include the use of molecular and cell biology approaches together with engineering principles in developing cellular and tissue engineering strategies for organ regeneration and assessment of human health risk. He received his B.S. in chemical engineering from Aristotle University of Thessaloniki, Greece, and his M.S. and Ph.D. from the State University of New York at Buffalo. He was a postdoctoral fellow at Rice University.*

for graduate students and upper-level undergraduates at the University of Oklahoma (OU). Biochemical and biological engineering are broad fields undergoing rapid development and have many opportunities for students to write research proposals on the advancement of science and engineering. We found that the great majority of students could write proposals on biochemical and bioengineering topics without major problems. Writing the proposal in stages over at least half the semester—with feedback provided by the instructor after each stage—was helpful to the students. Our findings are supported by our own observations and an anonymous survey of the students.

RESEARCH PROPOSAL

A research proposal was required in each of the following courses, with the number of students indicated in parentheses: Biochemical Engineering (25), Biosensors (9), Cellular Aspects in Tissue Regeneration (9), and Tissue Engineering (15). Each of these courses is an upper-level engineering course for juniors, seniors, and graduate students. Students devoted at least half the semester to developing their research proposals in these courses. While the requirement to do a research paper did not cause a reduction in course material covered in lecture, there was a reduction in homework required compared to what it would have been had a research proposal not been required, especially near deadlines for the research proposal.

The proposals ranged from a series of graded writing assignments (objectives, rough or first draft, and final draft in Biochemical Engineering and in Tissue Engineering; objectives and final draft in Biosensors), to one writing assignment for the entire proposal (Cellular Aspects in Tissue Regeneration). For one of the proposals (Cellular Aspects in Tissue Regeneration), the students were required to give a presentation, and feedback from that presentation was incorporated into the final written proposal. A sample outline of requirements and the general grading guidelines for the research proposal in Biochemical Engineering are given in the Appendix.

The selection of the research topic and development of the objectives and significance by each student were very important to successful proposals. Examples of statements of objectives and significance from our own research were handed out to students as guides. Students were allowed to choose a proposal topic in which they had an interest, based on their own research and/or prior courses in the biological sciences or bioengineering. (Nearly all of the students in the courses were either graduate students in the area of bioengineering or were undergraduates who were in one of the bio elective patterns—biotechnology or pre-med.) In some cases, students read ahead in the textbook about topics of interest. Each student met with the instructor to discuss the appropriateness of his or her chosen topic. It was sometimes necessary for a topic to be modified based on the instructor's experience and knowledge of the topic.

Students were given guidance about how to search the literature. In one course, Biochemical Engineering, a university librarian came to class and gave a presentation on the various resources available for searching literature, including the use of search programs and interlibrary loan.

OBSERVATIONS AND OUTCOMES

Our main observations were the following:

1. *Writing a research proposal was a challenge for students in these four courses. It was the first time any of them had been required to write a proposal, with the exception of a few students who had written a proposal in one of the four courses in a prior semester. For many of them, it was the first time that they had been required to do reading outside of the assigned textbooks. In addition, we observed that students tended to underestimate the difficulty of writing a proposal, especially in coming up with new ideas to research.*
2. *What separates this assignment from a traditional term paper is that, besides needing to understand the literature, the student also has to develop his or her new ideas for research. Challenging students to develop new ideas and to express them in writing is what we see as the major reason to use this assignment.*

TABLE 1
Summary of an Anonymous Survey of Students About the Research Proposal in Bioengineering Courses

Statement	Percent of Respondents			
	Strongly Agree	Agree	Disagree	Strongly Disagree
The research proposal was a good way to learn about a topic in bioengineering in depth.	64	29	7	0
The research proposal involved more creativity than any other assignment I have had while at OU.	21	43	36	0
The research proposal gave me a better appreciation about how new technology is created.	14	58	21	7
The research proposal was one of the most challenging assignments I have had at OU.	21	43	29	7
Writing a research proposal in this course helped with another course/courses taken afterwards and/or a research project.	36	64	0	0

3. *Breaking the requirements down into segments (such as a summary with specific aims, a rough draft, and a final draft) due on different dates helped make the assignment more manageable for the students. Giving students written or oral feedback about each segment helped students improve on the next segment due.*

By the final draft, a great majority of students were able to produce a proposal without major problems. We found that roughly one-fifth of the students wrote proposals that presented new and unusual ideas, were well explained, and could serve as the basis of a proposal to a federal granting agency. Undergraduate students performed about the same as graduate students on the proposals.

Our observations, based on talking to students about their proposals and reading students' proposals, were confirmed by an anonymous survey of the participating students. Survey results are summarized in Table 1 and selected student comments are given in Table 2. By a large margin, students thought that the research proposal was a good way to learn about a topic in depth. A majority of the students either agreed or strongly agreed that the research proposal involved more creativity than any other assignment they had completed at OU, gave them a better appreciation of how new technology is created, and was one of the most challenging assignments they had at OU. All of the students either agreed or strongly agreed that writing a research proposal in the course helped with another course taken afterward and/or helped with a research project. The student comments shown in Table 2 reinforce the survey results in Table 1. A couple of the comments support breaking down the assignments into segments; these comments were given in response to a final question in the survey about ways students thought the research proposal assignment could be improved.

The writing of research proposals by students addresses ABET criterion 3(i): ". . . a recognition of the need for and ability to engage in lifelong learning." Writing a research proposal helps students to learn in a structured way how to create new technology, which will serve them in the future as they are confronted with new problems and challenges.

Besides being used as part of a biochemical or biological engineering course, a research proposal could be used as the requirement to fulfill an undergraduate research course (for example at OU, the courses Honors Research, Undergraduate Research Experience, or Senior Research). A research proposal could also be required in other upper-level engineering courses on topics where technology is advancing rapidly.

CONCLUSIONS

We conclude that requiring a research proposal provides an excellent learning experience for upper-level undergraduates and graduate students in biochemical and biological engineering courses, especially when the proposal writing is divided into stages over at least half the semester. Writing a research proposal requires a higher level of thinking than a normal term paper, where the student is typically required to review the technical literature on a given topic. By proposing new research, the student is required to think more about existing research and consider how to advance science and technology in the field.

TABLE 2
Selected Comments From an Anonymous Survey of Students About the Research Proposal in Bioengineering Courses

"The proposal requires background research that enhances and reinforces the concepts being conveyed in the coursework."
"It increased my knowledge about the subject, and it was stimulating trying to produce something 'new' from the course."
"The research proposal helped us learn things that were beyond what could be covered in class. It was a good opportunity to see how the general concepts of bioengineering apply to different areas."
"Having to plan and design experiments was very challenging in terms of creativity. The research proposals were out of our area of research; thus, we had to be very creative in developing concepts and ideas for the project."
"I had to pull knowledge from quite a few areas and tie them together. It gave a stronger appreciation for those areas in which my knowledge is weak, and forced me to do a fair amount of literature review for those areas."
"I would say it is the most challenging assignment I had at OU after the capstone project."
"It helped me in writing my thesis."
"The assignment helped me formulate cohesive scientific thoughts, and helped me learn to focus my arguments for my dissertation writing. The most important aspect of the assignment was the focus on taking a scientific idea through the research design paradigm. Learning to write clearly, concisely, and scientifically is an essential skill and should always be practiced."
"It has helped me in writing research proposals in my own research and for my general examination."
"I strongly believe that a complete and full workup of a rough draft (*i.e.*, what a student 'thinks' is a final version of the paper) should be turned in at least three to four weeks prior to the end of the semester. This way the professor can be critical of the writing, and the student would still have time to learn about what was written incorrectly and how to remedy that. The specific aims should be submitted within four weeks of the beginning of the course, in my opinion."
"Actually, I thought that it was a great experience. While doing it, I thought that it was more time consuming than it was worth. However, in retrospect I think that it was extremely valuable."
"I like the way there were several deadlines along the way before the final proposal was due."

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APPENDIX

Sample Outline of Requirements for the Research Proposal in Biochemical Engineering

Each student is required to write a research proposal on a topic associated with the production and processing of bioproducts. Specific topics include, but are not limited to, fundamental studies of:

Molecular and Cellular Engineering. This expanding area of engineering research encompasses pure and mixed culture processes, modeling, optimization, and control of cell and metabolite production, development of new biochemical reactors, biocatalysis, and conversion of synthetic gas and other chemical feedstocks to value-added products via biological means. New techniques in the monitoring and control of molecular and cellular engineering are also of interest.

Downstream Processing. The capability to purify bioproducts in a cost-effective manner on a commercial scale is an important technical goal in bioprocessing of substances of biological origin. New processes and a major enhancement of existing processes are needed to accomplish necessary purification.

Guidelines

1. *Objectives and significance: Write one to two pages giving the objectives of your proposal and the expected significance. Innovative or original aspects of the objectives should be discussed. Also, on a separate page, give the complete citations, including the titles, of five or six literature references that relate to your proposal.*
2. *Each proposal (initial draft and final draft) must include:*
   - *A. Project Summary – limit one page*
   - *B. Project Description – limit 10 pages*
   - *C. References – no page limit*
3. *The project description should be a clear statement of the work to be undertaken and should include the following: objectives for the period of the proposed work and expected significance and relation to the present state of knowledge in the field. The statement should outline the general plan of work, including the broad design of activities to be undertaken, and an adequate description of experimental methods and procedures. Typical section headings of the project description are as follows: Objectives, Significance, and Impact; Background; General Plan of Work; and Experimental Methods and Procedures.*
4. *Specifications for margins, spacing and font size: 2.5 cm margins on top, bottom, and on each side; double spaced; and 12-point font size.*
5. *Web site references should be limited to business and government Web sites only. All other reference citations should be to peer-reviewed articles in published journals.*
6. *For the revised proposal, any changes made to the initial proposal should be underlined or highlighted.*

Grading/Schedule

The grade for the research proposal will be based on the following criteria:

1. **Approach.** *Are the conceptual framework, design, methods, and analyses adequately developed, well-integrated, and appropriate to the objectives of the project?*
2. **Innovation.** *Does the project employ novel concepts, approaches, or methods? Are the objectives original and innovative? Does the project challenge existing paradigms or develop new methodologies or technologies?*
3. **Utility or relevance of the research.** *This criterion is used to assess the likelihood that the research can contribute to the achievement of a goal that is extrinsic or in addition to that of the research field itself, and thereby serve as the basis for new or improved technology or assist in the solution of societal problems.*

Grade Credit and Schedule:

Selection of proposal topic (due after three weeks)	0%
Objectives and significance (due after six weeks)	5%
Initial draft (due after 10 weeks)	20%
Revised draft (due after 15 weeks)	15%
Total for the proposal	40%

General Grading Guidelines for the Research Proposal in Biochemical Engineering

The one- to two-page statement of objectives and significance was graded based on the degree to which the objectives were specifically stated. The statement of significance should describe what is innovative about the proposal.

The initial and revised drafts of the proposal were graded based on a careful reading by the instructor, with comments and questions written where appropriate in the margins. The questions and/or problems about the proposal led to a rating of the proposal into one of three categories: minor, moderate, or major questions/problems. In addition, the objectives and significance section of the proposal was checked to see if any deficiencies noted in the earlier objectives and significance assignment were corrected. Numerical grades were assigned based on the degree to which questions and/or problems were minimal and the objectives and significance were well stated. ❐