Biochemistry Idea Papers: Teaching Proposal Writing

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Abstract: A biochemistry course for upper-division students builds valuable skills for students seeking industrial positions or to continue their education. Some of these skills are the abilities to think critically, read the primary literature, write coherently, and come up with new directions for research. This assignment pushes students to gain mastery on a topic of interest, develop a preliminary idea, and develop scientific writing skills. This paper describes how this complex activity can be incorporated into the undergraduate setting, using finite steps to facilitate student success.

Introduction

Many articles have addressed writing assignments for students in chemistry courses [1]. The most recent articles report assignments that reinforce concepts [2–5], connect chemistry with daily life [6–8], or expose students to literature [9, 10]. Few papers address having undergraduates write research proposals [11, 12].

Successful professionals must be able to write well, develop good ideas that are supported with evidence, and explain systems. Proposal writing is important for chemical professionals because of the need to accrue funding for equipment and research supplies, whether internally or externally [13]. With the increasing public pressure to justify scientific and medical expenditures, government and other granting agencies are funding those proposals that do the best job of explaining the relevance of the research. Graduate programs continue to value proposal writing experience and it remains a graduation requirement at some universities [14].

The explosion of scientific, and particularly biotechnological, information has brought with it the coverage-versus-depth issue. Scientists typically choose coverage because of the formidable entrance exams (MCAT, subject GRE) and the fact that knowledge is cumulative in the sciences. I believe we undervalue the student learning that can come from direct engagement with one issue. The nature of this assignment forces students to delve into a topic in biochemistry that intrigues them. Because of the individualistic nature of this assignment, most of the work involved takes place outside of class time and is student-driven.

Proposal writing challenges students and faculty members. The use of this assignment in class generates meaningful discussions about the breadth of biochemistry and brings current issues to the forefront. I use this assignment as an addition to the traditional material covered in a biochemistry course populated by biology, preprofessional (e.g., premedical, preveterinary), and chemistry majors. Assisting approximately 30 first-semester biochemistry students and evaluating their proposals increase my skills and validate ongoing involvement with the biochemical literature.

The Assignment

The ultimate goal of this assignment is to have students write a five- to seven-page research proposal, beginning from the primary literature. Students are not required to carry out or be able to complete the work they propose, nor are they required to elaborate on experimental details in the proposal. It is very important that students identify the importance of the work, justify their idea, and utilize the primary literature. Students are given a sample proposal, format guidelines, and grading criteria for this assignment.

Purpose of a Series of Assignments

The task of writing a five- to seven-page proposal including embedded figures and/or equations is formidable for undergraduates. In order to use this exercise as a meaningful learning experience, it needed to simulate all the parts of the proposal writing process. I segmented the process into a series of assignments: topic idea, rough draft, peer review, and final draft. Each assignment had a deadline, with the whole process extending over approximately eight weeks of the semester (Table 1). By segmenting the project, I allowed for multiple opportunities to provide feedback and to redirect students if necessary.

Topic Idea

Most students have read some primary chemical or biological literature by the time they are college juniors. However, I do not assume that they understand how to utilize the literature to generate an idea. We discuss resources in class such as faculty consultations, interlibrary loan, MedLine, research libraries, reference librarians, and the Writing Center staff. During one class period each student finds examples of peer-reviewed articles, editorials or commentaries, and news articles in a variety of journals. We discuss the values and pitfalls of different resources and article types.

I also talk about the process of searching for knowledge gaps when you are a newcomer to a field. I tell them to discuss topics and ideas with everyone, scan journals, and to work on multiple ideas simultaneously. It is not unusual for students to spend a considerable amount of time investigating a preliminary topic only to find that they have no ideas in this area. I have found that I can reduce their stress by steering them away from topics that are highly evolved and by giving an estimate of the reduction from interesting topics (~100) to preliminary ideas (~10) to final ideas (1–2).

Table 1. Timetable Based on a Sixteen-Week Semester

Assignment	Semester Week	Class time used (in days)
Details of the assignment and strategies for using the literature for idea development.	1–2	1–2
Idea due date.	4–6	0
Rough draft due date and peer review.	8–10	1
Final draft due date.	10–12	0

Student-generated ideas do not have to take into account resource limitations at our university. Ideally their idea should be developed so that the basic technique and/or experimental design is outlined. The answer to their research idea must not be in the literature, but journal articles must provide precedents for the experiment(s) they outline. Ten references, with a minimum of five peer-reviewed articles, are adequate for quickly assessing precedents when article titles are provided.

Students typically turn in viable, albeit not well-defined, short passages about their idea(s) for me to comment on. Their goal is to sell a topic to me, as they might with a preliminary proposal to a research supervisor or funding agency. Since the process is evaluated at such an early stage, students are encouraged to seek information and get assistance in generating additional, more concrete ideas. I use the idea checkpoint as a way to provide resources, ask leading questions, and direct students to the most interesting ideas possible.

Rough Draft

The reality of writing is that one must allow time for revisions. This is also true of the proposal writing process. Students are good at putting papers aside until just before the deadline and they do not take revisions seriously. By having a rough-draft deadline, students realized that there was an opportunity to get an idea of how much more they need to work on their paper.

I encourage students to take the rough draft seriously. They are reminded that both the draft and final copy must be turned in to receive a grade for the paper. The rough draft is what their classmates will review. I supply an “estimated grade” to the draft that is predictive of what the paper would earn if it were their final draft. This estimated grade is not recorded, but allows me to gauge the current status of the papers and encourages meaningful revision. I am particularly critical of references and the concreteness of their research idea, although I do not neglect errors that detract from the clarity of the paper. Students value the comments made on their rough drafts more seriously than on papers where I allow rewrites after a grade has been assigned.

The closer the draft version of the paper is to the final draft, the closer the estimated grade is to the final grade. Since students are required to turn in rough drafts along with their final draft, adequate revisions automatically result in a one-letter-grade improvement. Obviously, students who do a good job on the rough draft have less work to do toward the end of the semester.

Peer Review

The peer review process is how scientific proposals are commonly evaluated. During one class period students read and critique proposal drafts by several classmates. Written student comments on peer work are made on separate forms. The forms request information about ease in understanding, the value of the idea, writing, and the assignment of a grade. After reviewing two to four other student papers, the review forms are collected.

Student comments are utilized informally as I write comments on each draft. I strategically select the most useful student comments and incorporate peer-derived information in my critique. This keeps the reviewer’s comments anonymous, an important fact since many reviewers are too lenient or too harsh. I do not want to send student writers mixed messages or to discourage them.

Final Draft

The final draft is submitted with the rough draft that students utilized for revision purposes. By having spent the bulk of the grading time on a rough draft, grading the final draft is much quicker. I check to see that the comments on the rough draft have been addressed. The estimated grade gives me an idea of where the paper began. Some students make tremendous improvements in their papers and the grades go up accordingly. Final drafts are the culmination of the student writing experience and strongly resemble short proposals to a funding agency.

Grading Criteria

These exercises are important, require serious self-study, and are difficult for undergraduates. Therefore it is important that this experience has a high grading value. It is not unusual for this to be a significant component of the total points possible in the course. I have given this assignment as much as one quarter of the final grade, although it takes only 2–3 class periods.

Approximately half of the points result from participation in the process; the remaining points are used to evaluate the final product. The idea, rough-draft, and peer review points are assigned based on meeting the deadlines and giving meaningful feedback to classmates. If one of these items is late or of very poor quality, a penalty is applied. The estimated grade assigned to each rough draft is based upon scientific content, originality, references, and the clarity of writing. I estimate low to encourage the revision process and significantly improve the overall quality of the final product. It is not unusual for me to estimate drafts at the D and F levels if they do not present a research idea. I have found that the lower the estimated grade, the harder students work to improve and the more apt they are to earn several letter grades higher. Final drafts are evaluated on the same criteria as rough drafts, with an automatic one-letter-grade improvement from the estimated grade. This improvement is to reward rewriting and revising the draft, a task students abhor.

Table 2. Selected Student Idea Topics

Topics	Topics
Interleukin-2 airway epithelial expression in asthmatics	Apolipoprotein B-100 truncation and its effects on cholesterol biochemistry in mice
Physical properties of spider silk and sequencing	Acid fibroblast growth factor antibodies and angiogenesis inhibition
The effect of fertilization and development on heat shock proteins	Analysis of biopterin in vitiligo cell melanocytes
A study of estrogen receptor site antagonist structures	Crohn's disease and the immune system
Detecting sperm membrane proteins that result in successful sperm competition	Detecting amoebae in legionellosis patients using metal ions
Serotonergic neurotransmitters, metabolites, and human aggression	Resveratrol as a chemopreventative in cancer cells
Inhibitors of rhinovirus 3C proteinase	Stress induction in tomato plants
D-1 and D-2 like dopamine receptor agonists and nicotine addiction	Exercise related muscle injuries
Purifying the BSE agent that stimulates prion protein misfolding	Soybean cyst nematode adherence and soil nitrate influence
Antifreeze proteins in *Rana sylvatica*	Aminoglycoside antibiotics and AIDS
Synthetic bone graft materials and lumbar vertebrae replacement	Mutation impact on metalloproteinase-3 tissue inhibitor

Implementation Issues

Millikin University does not have a biochemistry major, although we do offer one year of biochemistry, one semester of biochemistry laboratory, and a chemistry major biochemistry emphasis. The first-semester class size is typically thirty students; ten or fewer students take second-semester biochemistry. This assignment takes the maximum number of our students to the next level of critical thinking and writing.

I use this assignment in my first-semester biochemistry course instead of grading homework sets. All Millikin junior and senior biology and chemistry majors have taken an introductory course in research methods. Some students have familiarity with the primary literature and some are engaged in undergraduate research projects. Our students are incredibly self-motivated when allowed to select their own topics; reducing student topic options, however, may be a useful strategy for larger enrollments or to facilitate the use of graders. The average time taken to grade each idea, rough draft, and final paper is an hour per student, which is half the time typical of reviewing a proposal for a funding agency.

Outcomes

I have not been disappointed with this process or the outcomes. Students have written about a wide variety of biochemical topics (Table 2). They gain basic skills in proposal writing as well as an appreciation for their topic. Students enjoy becoming experts and they like sharing their ideas with scientifically literate peers. Even students who struggle through the initial steps of idea formulation and rough-draft writing turn in surprisingly good final drafts. The knowledge base of biochemistry changes so rapidly that information is quickly usurped by new studies, so plagiarism is not common.

Students who have gone on to graduate school or to interview for jobs are especially appreciative. They write back to say that because of their experience, they were able to discuss a biochemical topic in depth, talk about the proposal writing process from experience, and/or write a proposal of their own. I have also had students say they felt it was an important advantage in graduate school.

An added benefit of this assignment is the stimulation it provides me as a biochemist and instructor. I am always impressed and challenged with the diversity of topics that students select. Assisting students and evaluating their proposals force me to stay current with the literature. Their idea papers further my understanding of what students are interested in. I find it extremely invigorating to read the final products that students submit. It is equally heartening to see how undergraduates can delve into the primary literature, critically examine an issue, and develop a biochemical idea.

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