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Use of a Grant Writing Class in Training PhD Students

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Abstract

A well-written application for funding in support of basic biological or biomedical research or individual training fellowship requires that the author perform several functions well. They must (i) identify an important topic, (ii) provide a brief but persuasive introduction to highlight its significance, (iii) identify one or two key questions that if answered would impact the field, (iv) present a series of logical experiments and convince the reader that the approaches are feasible, doable within a certain period of time and have the potential to answer the questions posed, and (v) include citations that demonstrate both scholarship and an appropriate command of the relevant literature and techniques involved in the proposed research study. In addition, preparation of any compelling application requires formal scientific writing and editing skills that are invaluable in any career. These are also all key components in a doctoral dissertation and encompass many of the skills that we expect graduate students to master. Almost 20 years ago, we began a grant writing course as a mechanism to train students in these specific skills. Here, we describe the use of this course in training of our graduate students as well as our experiences and lessons learned.

Keywords critical thinking, graduate training, hypothesis testing, scientific writing

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Our goal in graduate student training is to arm our trainees with skills that will enhance their future success, regardless of the chosen career path. Among the most critical of these skills is scientific writing. Despite the importance of scientific writing skills, training in this area is often highly variable and dependent on individual thesis mentors. To address this gap in graduate education, nearly 20 years ago, we started a formal graduate course in scientific writing that employs grant writing as the training vehicle.

Grant writing often gets a bad reputation. Certainly, this activity is time-consuming, takes researchers away from the actual performance of their research, training or teaching, and can be frustrating when unsuccessful at securing the funds needed to continue the research. However, the act of preparing a grant application also forces one to devote concentrated time to reading in a focused area and thinking deeply about the most important questions in the field as well as how to devise defensible approaches to answer them. A successful grant application is likely to have a well-reasoned argument that is logical and persuasive, requiring strong writing skills to convey these aspects of the work. Such writing requires large amounts of time spent editing, and is ideally performed with the aid of

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critical and iterative feedback from colleagues. Regardless of the success or failure of the funding decision, the act of writing a strong application is time well spent and contributes to strengthening the science and the scientist. With this reasoning, we developed a grant writing class for early stage graduate students in the biological and biomedical disciplines. The class was first taught in the Biochemistry, Cell & Developmental Biology (BCDB) graduate program in 1998 and was later incorporated into the training of almost all students in the Graduate Division of Biological and Biomedical Sciences in the Laney Graduate School of Emory University.

A number of perceived deficiencies contributed to the decision to use grant writing as a training exercise for early stage graduate students. Have you ever been a member of a thesis committee and realized that the student has not read deeply in their field, despite being in their third, fourth or even later years in their laboratory? Have you ever seen a student struggle to find a good thesis project for one, two or more years? Have you read a 200-page doctoral dissertation written by a student who fails to grasp the fundamentals of sentence, paragraph or chapter organization and structures or who has never written down a logical argument? Have you lamented the apparent 'lack of ownership' of a project by a student or one struggling to make the transition to independent researcher (1)? If these issues have concerned you as a mentor or anyone involved in training graduate students in the science, technology, engineering and math disciplines, then you likely have sought ways to improve the training, learning and outcomes. Through our experiences, we have learned that the writing of a strongly reasoned and carefully assembled research proposal provides outstanding opportunities for training in the skills that embody the best of graduate education.

We should mention that not all faculty at the time of our course's origins believed this was a good idea. Many thought students in their first 2 years were not prepared to take on this onerous task. Others preferred that their students get into the laboratory and start generating data, which could be written about at some later date. Still others, knowing the amount of work required, simply thought the students' time could be best used in other ways. Make no mistake about it, the way that we propose this course be done optimally is as a time-intensive, full semester long enterprise that incorporates a great deal of time for editing and re-writing as well as input from as many others as possible. We know of no better way to improve writing skills and view the seeking of and responding positively to all criticisms as incredibly valuable life and professionalization skills. Thus, editing repeatedly, seeking out critical feedback (some of which may be conflicting) and incorporating feedback into later drafts are required. This process contributes directly to the 'ownership' of the project and huge improvement in the writing.

We describe below the key aspects of the current course taught in the BCDB graduate program at Emory. This class has evolved over the years, as we continually seek ways to optimize the educational experience for our students. In later sections, we list what we perceive to be the largest advantages and challenges to such a course, along with some of the issues arising and how they were resolved.

Course Design

Our grant writing class, titled 'Hypothesis Design and Scientific Writing', is required for every student in the first (Fall) semester of their second year. Students in the BCDB program are expected to choose a research advisor/mentor at the end of their first year in the program, spend the summer in that laboratory devising a research project and gaining some initial experience with the central methods employed in that laboratory. They must then begin developing a defensible thesis proposal at the start of their second year. We are fortunate at Emory in the biological sciences that the Laney Graduate School provides support for all of our students for the first 18 months in residence. This support allows us to fashion a rigorous curriculum without incurring the wrath of mentors, who would otherwise be supporting the students, typically through their own research grants. The class meets once a week for 1 hour and 45 minutes and is team taught by two to three faculty members. Most research proposals are written on the topic of the student's thesis research, although this is optional (see below). During the course of the semester, each student writes a research proposal in the format of an NIH F31 pre-doctoral fellowship; specifically, the Specific Aims (one-page limit), Research Training Plan (six-page limit) and scientific and lay summaries.

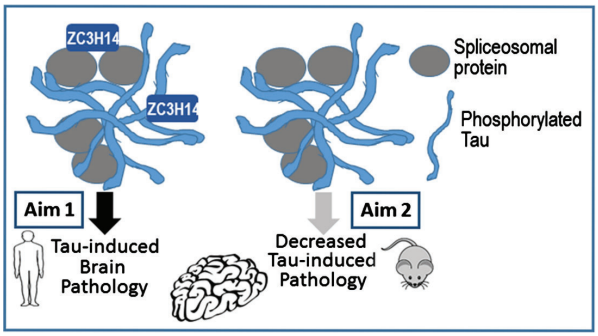

Figure 1: Example of a model figure that summarizes the aims of a proposal. In this example, Aim 1 examines whether the ZC3H14 protein is present in the tau tangles that contribute to brain pathology in Alzheimer's disease. Aim 2 tests whether genetic ablation of ZC3H14 decreases the tau pathology. Aim 1 employs human samples and Aim 2 uses a mouse model as indicated by the accompanying cartoons. We seek to have students summarize their aims within a very simple schematic representation. This model would generally be placed in the Significance section of the Research Strategy.

The written product

The Specific Aims page provides an overview of the big picture of the project, highlights the significance and overall rationale, followed by two specific aims that each include a hypothesis, rationale for that hypothesis and a brief description of how each hypothesis will be tested. Although not required by the NIH format, for consistency, class research proposals must be prepared with two specific aims, typically with two to three sub-aims in each. This one page is important to help the student understand the project as a whole and might be likened to a written version of an elevator speech or a 3-min thesis (developed at the University of Queensland, see: http://threeminutethesis.org/). This single page ends up being written and re-written multiple times over the course of the semester and as such helps teach the value in iterative writing and revision.

The Research Training Plan includes two sections, Significance and Approach. The Significance section is typically one to two pages and contains the background information required for the reader to understand and appreciate the importance of the problem addressed in the proposal. For the purposes of the class, the Significance section is required to include a figure with a model that summarizes the proposal as a whole and ideally illustrates the Aims (see example in Figure 1). The Significance section may also describe key preliminary data when available, although the best place to include such preliminary data (Significance or Approach section, with the associated rationale and experimental plan) is always a topic of debate in the class. The Approach contains the two specific aims, each of which are comprised of a statement of the aim, the hypothesis, rationale for the hypothesis and proposed experiments. The description of experiments contains the techniques to be used and controls needed, data analysis to be performed (specifically including the most appropriate statistical analyses), possible outcomes/implications and potential pitfalls/alternative approaches. In fact, we specifically require students to have labeled sections within each aim that consist of: restated aim, hypothesis, rationale, experimental approach, data analysis, possible outcomes/implications and potential pitfalls/alternative approaches. We find two components of this structure particularly critical and formative, the data analysis and the possible outcomes and implications. The data analysis section forces students to clearly state how results will be analyzed. We include rigorous treatment of statistics and also clear statements of how many biological and technical replicates will be performed. This section helps to introduce students to need for rigor and reproducibility in the data that they produce. For the possible outcomes/implications section, we require students to consider ALL possible outcomes and then through the implications, connect them back to their biological model. In contrast to the 'expected outcomes' sections that often populate grants, this complete consideration of all possibilities forces students to consider what it would mean if they did not get the expected result. We find this process to be highly instructive to these students who are in the process of developing their PhD project. At the end of the Research Strategy, we encourage students to include a short one paragraph summary that is typically included at the end of the six pages, to further highlight the potential impact to the field and training potential of the research design.

In addition to the Specific Aims page and Research Training Plan, preparation of the Project Summary/Abstract and Narrative (a brief lay summary) is also discussed to provide guidance on the formulation of succinct and accurate summaries of the proposal and its potential impacts for

both a scientific and lay audience. We also include guidance on the preparation of a *curriculum vitae* (CV) using the NIH biosketch as a model to guide students in preparing and updating their own CV.

Classroom activities

Students first meet with course directors approximately 3 months before the first formal class. At this meeting, students are instructed to use the summer to start thinking about and planning their research proposal and to meet with their mentors to further those goals. They are given a worksheet intended to help guide them in developing the foundations of their research proposals. Students are required to prepare written responses to each question and turn in their completed worksheet at the start of the course in the Fall. We have found that this process encourages reading of the literature and more focused thinking and planning over the summer that facilitates development of stronger research proposals during the course in the Fall. The worksheet poses a series of questions, including:

- What is the big picture of your research topic?
- What are the connections to human health?
- What published and/or preliminary data are key to the project?
- What is the long-term goal of your project?
- What is the overall hypothesis to be tested in your proposal?
- If successful, how will your proposed studies impact the field?

It also contains three questions to be answered for each of the two planned Specific Aims:

- What is the specific hypothesis to be tested?
- What preliminary data (your own, from others in your laboratory or published work) is available to support the aim?
- How will you experimentally test your hypothesis?
- What controls and types of statistical analysis will be required in your studies?

The first 2 weeks in the class itself are taken up with general discussions of hypothesis testing and scientific writing. Proposals written by students in previous classes are used to model the sections of a research proposal and provide examples of effective scientific writing. For these examples, we select proposals with clearly stated goals and rationales that lead to specific experimental plans that will necessarily answer key questions, regardless of the experimental outcomes. Proposals with well-organized sections that provide a logical progression of ideas that are readily understood by a broad audience are emphasized. We have also generated 'bad examples' of some proposal components that contain the most common mistakes or misconceptions we have found in student writing. Unfortunately, such examples are not difficult to locate, e.g. those including numerous grammatical errors, excessive acronyms or jargon and lacking in organization. The worksheets developed over the summer are also discussed. Topics include what makes a strong or weak hypothesis, the importance of generating testable hypotheses and the role of the Specific Aims page. The other sections of their research proposals are each topics for class discussion, as summarized in Table 1, in approximately the order in which they appear in the final proposal.

Each class period consists of a didactic lecture on a particular grant section, including strategies to communicate the information of that section in a precise and concise manner. Examples are employed to illustrate these strategies, drawing on grants from previous students in the course (with their prior approval) and information available through the NIH Reporter website (https://projectreporter.nih.gov/reporter.cfm/). In addition to the lecture portion, most class sessions incorporate a discussion-based or active learning component (Table 1). For example, early in the course, students present their proposal to the rest of the class in a required five-slide format that consists of: (i) title of proposal; (ii) introduction: what the problem is and why one should study this problem; (iii) model slide; (iv) specific aim 1 with experimental design and (v) specific aim 2 with experimental design. These presentations and the in-class writing activities trigger extensive conversation and allow students to adjust their thinking and writing to convince the reader of the importance of the proposed study and convey to the student the importance of reaching a broad audience. Through this combined didactic and active, peer learning the single class period serves as an important complement to the weekly writing assignments.

Table 1: Overview of course topics, in-class exercises and assignments

Week	Class topic(s)	In-class exercise	Assignment due
1	Course overview Research proposal organization and scientific writing	Discuss strengths and weaknesses of example grants	Read (at least) one example student grant
2	Specific Aims, hypothesis design	Read example Specific Aims pages Discuss strengths/weaknesses Begin discussion of student worksheets	Completed worksheet
3	Significance, model figure, preliminary data	Write out significance sub-headings and discuss	Revised hypotheses, big picture, long-term goal from worksheet
4	Student presentations	Students present their aims as a five-slide presentation for student feedback	In-class presentations of Specific Aims
5	Student presentations	Students present their aims as a five-slide presentation for student feedback	
6	Approach, NIH Biosketch	Write draft Biosketch and discuss student 'contributions to science'	Revised Specific Aims
7	Abstract	Read sample abstracts and discuss strengths/weaknesses/styles	Significance section
	Summary	Write and read out two to three sentence lay summary (Narrative)	
8	Endnote Final discussion, questions and feedback	Interactive session led by library personnel with hands-on Endnote exercises	Outline of Approach Specific Aims #1 and #2
9	Career goals and values of critical thinking and writing skills	Open discussion: student questions	Approach for Specific Aim #1
10	The NIH review process (study sections and scoring)	Open discussion: student questions	Approach for Specific Aim #2
11	Open discussion of any topic	Open discussion: student questions	Abstract, Project Narrative and NIH Biosketch
12	No class-submission week		Compiled proposal PDF for student review (Abstract, Narrative, Aims, Significance, Approach and Biosketch)
13	Senior student study section	Discussion of student reviewer comments	
14	No class-submission week		Submission of final revised grant for faculty review

Typically, the week after each grant section is discussed in class, drafts of that section are turned in for critiquing by the course directors. These drafts are reviewed by one of the course directors and returned to students with a rapid turn-around (the same or next working day). One to two weeks later, revised drafts are due. Comments by the course directors are designed to highlight weaknesses in writing, logic, hypothesis design or experimental approach. Students are encouraged to seek their mentor's feedback during the preparation of each week's assignment but, at selected times during the course (typically for revisions of major sections), mentors are *required* to confirm they have read and provided critical feedback to their student. The mentor is encouraged to focus on the same aspects as those listed above for the course directors. However, *re-writing of sentences* (*or more*) *by course directors or mentors is strongly discouraged*. Instead, weaknesses are identified and explained and it is up to the student to determine how best to improve the writing. It is readily conceded that this process adds substantially to the time required for critiquing and re-writing but is critical if students are to become better writers.

In addition to class time spent in discussing each section of the research proposals, sessions on hypothesis design, use of Endnote (Emory University has a site license so use can be required) for reference management, the appropriate use and standards of preliminary data (including statistical

analysis) and the NIH system of study sections and grant reviewing are also included in the syllabus and class discussions. NIH Biosketches are also described and every student is required to prepare and submit one with their final research proposal. It is worth noting that for most students this is the first time that they have had to put together this format of a CV and it serves as a starting point for what becomes a living document of their accomplishments throughout graduate school. Biosketches are later supplied to thesis committee members immediately prior to each thesis committee meeting in the BCDB program.

We also have students prepare project summaries and narratives for their proposals. These are each one paragraph and used to summarize the objectives and methods proposed, and the relevance of the studies, respectively.

At the end of the course, research proposals are 'reviewed' in two phases. Three weeks before the final deadline, penultimate drafts of each proposal are turned in. This complete draft consists of the Project Abstract/Summary (30-line limit), Narrative (three-sentence limit), Specific Aims page (one-page limit), Research Strategy (six-page limit) and Bibliography. Each grant is then sent for review by a senior (typically fourth year) student in the BCDB program who has previously taken the class. Within 1 week, the senior student is asked to submit written critiques and comments, and to meet with the research proposal's author to discuss. This deadline allows 2 weeks for the inclusion of that input prior to submission of the final proposal in the same format. We have found that this peer instruction is as, and often more, valuable than the final critiques from faculty. This approach also provides senior students in the program with the opportunity to acquire or hone their skills in providing constructive criticism from the act of grant reviewing. This too is invaluable training, as anyone who has served on a study section can attest. The final grant is then turned in and sent to two faculty members, not the mentor, selected from those with students in the current class or volunteers. Faculty scoring follows the NIH scale (1–9, with 1 best and 9 worst) using a guide that addresses each section of the grant covered in the course. These scores figure prominently, although are not sole determinants, of final grades for the course.

Note that each section of the seven pages of text that comprise the final research proposal will have been written or re-written at least four times and received critiques from five to six other scientists: at least one course director, the mentor, a senior student and two faculty reviewers of the final proposal. The evolution of the documents can be quite remarkable and a source of great pride for the students. This is often the first instance in which these science students have found such pride in their own writing and the process appears to make an impression as to the effort and value inherent in extensive editing of one's writing and in seeking out critical feedback.

Grant Writing Class as a Training Exercise Versus Assistance in Real Grant Preparation

As mentioned above but worth repeating, a well-crafted fellowship application requires that a student identify an important topic, define why it is important and summarize clearly and succinctly what is currently known in the field and where the critical gaps in our knowledge lie. Then, they must persuade the reader that they or their laboratory colleagues have important new data and/or expertise to apply to the problems in ways that will necessarily advance our knowledge and have a positive impact on the field. We argue that anyone with such skills will have few problems gaining employment in a wide range of professions and thus this training is central to optimal graduate school training.

However, as all institutes within the NIH now offer F31 student fellowships, there is a clear danger that students and mentors view our class as simply preparatory to a real fellowship application submission. As we have also used this class as part of a student's professional development, we have included class time devoted to an introduction to the NIH grant system, how the Center for Scientific Review and study sections operate, and how funding decisions are made. With our class concluding in the middle of a student's second year and the optimal time for an F31 submission being in the second or third year, it further fuels the idea that the class is intended as a grant preparation exercise.

Our belief in the value of the process of grant writing as a training tool is revealed by the fact that we began using grant writing a training vehicle more than 15 years before NIH funding opportunities became available to the

majority of our students. However, that fact is not enough to prevent some of our students and faculty from treating the course as a grant preparation exercise. While today this is inevitable, and even cited below as a strength, we urge anyone considering pursuing the development of such a course to incorporate into the class, in as many ways as possible, clear lines between these two objectives.

Although our focus in this course is to prepare students for future success, there is value in providing a student and mentor with a structured process to assemble a strong research component for an individual training grant. In fact, many of our students do use the proposal crafted and honed in the course as the basis for an extramural grant submission. As some measure of outcomes for these student grant submissions, the overall funding success rate (fraction of those students submitting fellowship application(s) who have received some fellowship funding support) for those students who entered the BCDB graduate program between 2008 and 2012 and applied for extramural funding is 76%. Thus, many students who use this course as an opportunity to develop a strong project have success in obtaining individual extramural funding. We believe that this success largely comes from providing a structured process to produce and edit key components of the proposal.

We have always found it remarkable that despite the importance of grants to the academic research enterprise, none of the course directors ever received formal instruction in the writing or preparation of research proposals. We have all experienced struggles and had occasion to witness colleagues struggle to obtain funding. We speculate that these trials and tribulations might, at least in part, be attributed to weakness in the associated skill sets described here. Furthermore, in reviewing actual grant applications, we routinely see proposals that suffer from poor grantsmanship, consequently making the evaluation of the proposed science more challenging. Thus, a grant writing course can also be an invaluable addition to postdoctoral training or that of an Assistant Professor. We have never failed to learn and increase our own skill sets from critiquing the work of others. In fact, in years of teaching this course, we have all honed and developed our own grant writing skills. Further, the engagement of colleagues in provision of extensive, critical feedback can foster a very positive, collegial atmosphere at any institution. We believe that the arts of critical thinking, hypothesis design and testing, logical and persuasive writing and the giving and receiving of critical feedback are skills that are invaluable in virtually all careers. But, we also urge caution when a student's work in the classroom is the result of too much input or includes input from anyone hoping to benefit financially from the use of the work in other contexts.

Advantages and Challenges

Some of our more senior faculty members remember graduate school as a time of lone investigations, often including a first year in the laboratory without a clear project. This training period had a potential to extend into the second year in the laboratory and beyond, and likely contributed to extended 'years to degree'. In addition, it was not uncommon in those earlier times (and may still be practiced today) to have students write research proposals as part or all of a qualifying exam process, prior to admission of students to candidacy for the PhD. However, to have such a requirement without specific training in the processes required to prepare a strong research proposal can be wasteful of time and even counterproductive to student training. We found that the process of generating a strong research proposal contributed in several positive ways to student engagement and progress toward the degree. Because there are many factors that influence metrics such as time to degree, we cannot document here a significant difference that results solely from our grant writing class. Thus, this essay is best viewed as a compendium of our anecdotal observations. We list here, by way of summary, what we perceive to be the most significant advantages and challenges in a grant writing class:

Advantages:

- The skills acquired from the grant writing process (writing, logical argument construction, hypothesis design and testing) are useful in all later careers.
- Requires that early stage students read extensively in their research area and encourages optimal usage of referencing (2).
- Students take an active role in formulating their testable hypotheses and specific aims.

- Teaches students how to appropriately display and discuss their data and the value of and how to generate impactful figures, including the use and description of appropriate statistical analyses (importantly, our graduate program trains students in the ethical conduct of research including sessions on data presentation and statistics and some of the training in this course is an ideal complement to those lessons).
- Leads to increased student ownership of their project early in graduate careers.
- Demonstrates the role of innovation and creativity in the research process.
- Helps students transition from course-taker to researcher (1,3).
- Demonstrates the importance of multiple drafts and careful editing to the generation of better writing.
- Demonstrates the valuable role for constructive criticism to sharpening of critical thinking (although whether critical thinking is specifically taught is arguable; see 4).
- Creates an environment that facilitates extensive mentor/mentee dialog concerning the project early in the training.
- Facilitates critical input from others into research designs that may be flawed or sub-optimal; thus, potentially saving the student months of effort and the mentor valuable research dollars.
- Provides early experience for student and mentor in working through a writing process that is invaluable for future publications including primary and review publications as well as the student's thesis project.
- Fosters a climate of shared critiquing of ideas and proposals that can propagate amongst both students and faculty members.
- Promotes real-life discussions of ethics issues in science, e.g. what constitutes plagiarism.
- Promotes peer training through in-class exercises and discussions and through organized roles for senior students (5).
- Team teaching increases the diversity of input to each grant
- Demonstrates to early stage students the value of a mentor who is involved and active in student development.

Challenges:

- Labor-intensive course for students, takes time from other things.
- Labor-intensive course to teach (ideally team taught), requiring rapid turn-around of weekly writing assignments.
- Time demands on course director(s) may limit the number of students per class.
- Requires that all students have settled into a laboratory and have a sufficiently developed project at the time the course begins (only if topic of students' grants are their own thesis research), and ideally a few months before that (to allow them to read extensively in the field before the grant writing begins).
- Problems can arise if projects change during the course, particularly late in the semester.
- Feedback can be highly variable in quality and even contradictory (note that, while challenging, this conflicting feedback can also be highly educational for students).
- Instruction in a 'classical' F31 may appear formulaic to students and conflict with non-hypothesis driven or other, alternative approaches to descriptions of research design.
- Single (NIH F31) grant format less directly applicable to other fellowship funding agencies (e.g. National Science Foundation or other foundations). Note, however, that reformulation of the proposal outside of the class could provide students opportunities to further develop scientific writing skills.

Issues Arising

(1) Who is the most qualified to teach writing?

When we began this course, none of the course directors felt qualified to teach writing, despite the clear understanding that improved scientific writing was fundamental to the process. We consulted all members of our graduate program (none of whom felt any more qualified) as well as those in our undergraduate English and Journalism departments, where we were basically told that the only way to teach writing is to make students write. While there is some truth to this, we believe it more accurate to say that the way to teach writing is to make students write, provide detailed

feedback on both general and specific defects in their work and then make them re-write and then repeat this process as often as possible. Students in higher education today are too often rewarded for turning in first drafts as final essays so the value of re-writing does not come readily to them. Thus, any faculty member willing to put in the time to read carefully and provide detailed comments (not re-writing) is more than qualified to teach such a course. Rewarding those efforts on the part of such dedicated faculty is a future goal and a challenge.

(2) What is the best time to schedule the class in a graduate program curriculum?

The answer to this depends to a large degree on how the graduate program is structured and financially supported. Because the course is so demanding of students' time, it is best incorporated into the period that is supported by the graduate school or program. When the mentor is paying the student stipend (e.g. off a research grant), it is reasonable for them to expect their students to be working full time on the research. This consideration serves to force the course early in the curriculum; in the BCDB program, the course is required for all students in the Fall semester of their second year. Ideally, the students in the course will have identified the mentor of their dissertation research and had the opportunity to spend some time discussing and developing, with as much precision as feasible, the topic of their project. We strongly encourage students to do as much of the background reading for their project over the preceding summer before the grant writing class begins. This approach allows better use of their time in formulating critical, testable hypotheses and working on their writing skills during the course.

(3) Why not simply send your students to a workshop on grant writing?

It is increasingly common for science societies or other groups to host grant writing workshops or courses. These typically last from one or a few hours to several days and are usually directed at a specific subset of scientists, e.g. students, postdoctoral fellows and junior faculty members. They can convey a tremendous amount of important information that can save the attendees a lot of time and help them gain funding at critical times. However, they simply cannot teach the key skills that we emphasize in our graduate school course and that provide the most important benefits to our students. Acquisition of critical thinking, hypothesis design and scientific writing skills takes a great deal of time and hard work to improve over an extended period and cannot be gained in a few hours. Furthermore, our course has weekly assignments allowing time for feedback, editing and revision that cannot be gained in a focused workshop format.

(4) Should the topic of the grant be the same or necessarily different from the thesis project?

There are good arguments on both sides of this question. When we began the course, we required that students choose a topic for their grant that was different from their actual dissertation research. One argument in support of this model was our concern that students who have access to their mentor's funded grant applications or other writings would be overly influenced by those and not challenged to generate their own ideas, aims or proposed solutions. Then, upon completion of the course, students would start anew with writing on their real research topic. This issue has proven not to be a problem in our opinions, at least in part because any funded grant application is typically at least 1 year out of date and because students are challenged in the course to develop their own ideas from all available, current information.

Today, we allow students to write on any topic they choose and overwhelmingly they use their thesis project for their class research proposal. We learned along the way that the extensive reading for comprehension, synthesis of the field, creation of new models or ideas, generation of testable hypotheses and logical writing required to convey all those things position our students optimally to launch on more productive and independent research years. We speculate that this process aids in the transition from course-taker to researcher (1,3). By allowing them to write about their own research, they are much more actively engaged and challenged to think deeply about the field and develop defensible models. While having students in a class work on their writing using a format that can be readily turned into a grant application for real financial support seems to provide added incentive for them to put in their best efforts, it also can present some ethical challenges to both the course directors and the students (see below).

(5) What is the role of the thesis advisor/mentor in the grant writing class?

With the topic of the students' grants largely defined by current and former work performed in their mentor's laboratory, the mentor is clearly the person most knowledgeable about the topic and best able to judge novelty, impact, feasibility and overall quality of the research proposal. Thus, they are a critical component in putting together a strong proposal. However, we have found that some mentors can object or perhaps even feel threatened by the fact that students in their laboratory are receiving critiques of ideas and research design that they may have originated. Thus, it is important to communicate the goals and procedures of the class to mentors and to listen to concerns that may arise. We require that mentors confirm they have read and provided comments on drafts of each student's work at least three times during the course of the class. We (and students) have found the extent and value of this input to be highly variable as a result of several factors, e.g. limited mentor time, mentor travel or lack of communication between the student and mentor ('Dear Dr X, my grant is due at 0900 h tomorrow morning and you are supposed to read and comment … can you please do so by then?'). It is important that course directors communicate clear instructions to each mentor with regard to the value of their input to the student's work and the limits of the editing they should be giving to their student.

In efforts to further increase communication between course directors and mentors, we now ask each mentor and student, prior to the course, to sign a registration form stating that the student will be allowed to follow the grant format for the course. The students agree to standard course requirements including the required attendance and homework deadlines. The form is more critical for mentors as we ask them to ensure that they will provide students with prompt feedback on writing assignments, allow students to follow the grant format required for the course and serve as reviewers for student grants (other than their own student) to aid in grading at the end of the course. The mentor commitment and buy-in is critical to the success of the students in the course so this document ensures that mentors are aware of their roles and required contributions.

During the course, conflicts can still arise from students receiving differing feedback or suggestions from course directors and mentor. In the case of conflicting scientific feedback, this provides the student with real world experience in how to consider constructive criticism and incorporate or reject specific suggestions. In the case of proposal formatting issues, students are reminded that the research proposal produced in the class is graded based on a rubric developed for the required format. Furthermore, the registration form includes a statement that faculty mentors will allow students to follow the grant format provided in the course.

(6) Ethics and grant writing classes

When we began our grant writing class in 1998, there were almost no opportunities for graduate students in Biochemistry or Cell Biology to submit grant applications for actual funding. This situation has changed dramatically in recent years as all the NIH institutes now support F31 training fellowships. Thus, students in all areas of basic biological and biomedical sciences can compete for them. This has created a great opportunity for our students not only to gain very real and substantial benefits from their hard work in the grant writing class but has also created an environment in which mentors are increasingly tempted to play an active role in the preparation of their student's grant in our classes. In the worst case scenario, the student can even get caught between instructions from an over-zealous advisor intent on getting money to support the laboratory through funding of the student and those from course directors intent on crafting what they think would make the best grant. This conflict has, on rare occasion, even taken the form of advisors telling the students to cut and paste whole paragraphs from their funded research grants to use in the students grant writing class application 'because it is so well written'. The issue and definition of plagiarism have arisen regularly in this class so much that these topics have become the subject of classroom discussions, including specifically in our program's Responsible Conduct of Research workshops. We have also found that requiring students to have two aims with specific sections in each aim is a sufficiently different format from any faculty member's grant thereby decreasing the likelihood that students will merely copy and paste from the mentor's grant.

Critically, both students and their advisors must be clear on the differences between work that is performed and turned

into course directors for credit as part of a class in the university and a graduate fellowship training grant that is submitted to an outside agency for funding consideration. Clearly, neither should tolerate plagiarism and students and faculty need to be as clear as possible on where the lines are. When a student turns in work for credit in a university that can be documented to have been plagiarized from any other source, the student must understand that it puts them at risk of being accused of an ethical violation, *even if they have been advised to do so*.

We, as course directors, play no role in the submission of student grants for funding to any outside organization, beyond training students in the skills that contribute to them being successful in doing so. Indeed, students in our graduate program have been remarkably successful in receiving funding for training fellowships in recent years. We take significant pride in the belief that the training provided in our class contributed to their successes. This is now a very practical value to such training. However, we continue to emphasize the value of using the process of putting together a strong research proposal as an opportunity to train students in several critical professional skills that will serve them well throughout their lives and in any later professional career.

Resources to Support a Writing Course

When our course began, there were precious few resources to aid students or course directors in pre-doctoral fellowship grant writing. The one found to be most useful, and even more so for junior faculty members faced with writing their first R01s, was 'Research Proposals: A Guide to Success' by Ogden and Goldberg (6). This resource has become a bit dated (e.g. R01 applications were still 25 pages in length when this was written) but still contains lots of invaluable and clear advice as well as useful examples of strong and weak writing. There are a number of helpful resources available to grants writers today, including books focused on the F31 fellowships, e.g. 'A Practical Guide to Writing a Ruth L. Kirschstein NRSA Grant' by Hollenbach (7). Some of our students have identified 'A Short Guide to Writing about Biology' by Pechenik (8) as helpful to them in working on their writing skills. This book is written for those writing manuscripts and not grants, but still full of great information and advice including useful details of how to put together figures and present one's work.

Conclusions and Implications

The academic community is in the midst of a conversation regarding how well the training we provide for our graduate students positions them for future success in an ever broadening career landscape (9–14). We believe that training students to invest substantial amounts of time in the planning of optimal research strategies with input from a range of colleagues is a significant benefit of this course. When this training is coupled with specific strategies to communicate clearly and convincingly in their writing, students are likely to emerge from graduate school with these very marketable skills making them valuable hires to a wide range of employers. We believe that these skill sets embody the very essence of graduate training. Although our comments and course focus on experience in the training of students in the biomedical sciences, comparable approaches could be applied across disciplines as valuable and practical training tools.

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