



Guest Editorial

Special Issue: Annual Education Issue Writing a Review Article for Publication as Part of a Graduate Engineering Course

Writing and publishing peer-reviewed journal articles is the most essential component to disseminate scientific research. Yet, the vast majority of engineering doctoral students receive little to no formal writing training, making the task of outlining, composing, editing, and revising their first publication particularly daunting. Indeed, many Ph.D. students do not get first-hand experience writing peer-reviewed original research or review articles until late in their graduate careers when they have their own data to publish. Furthermore, the guidance that students receive on how to effectively write journal articles, as well as what is involved in the process, can vary considerably based on an individual's advisors and mentors.

Here, we describe our multiple experiences leading groups of engineering graduate students, as part of a course, to write comprehensive review papers with the goal of ultimately having them published in established, peer-reviewed journals [1–3]. Similar to what others have done [4], these efforts have been conducted as a natural outreach of graduate-level course subjects, *Cardiovascular BME and Imaging* (CJG) and *Mechanobiology* (CPN), in which no authoritative textbooks exist, and students spend significant time learning from a careful read of the primary scientific literature. While challenging, this exercise has been beneficial to both students and instructors, as it allows for the integration of course objectives with active learning strategies, beyond standard pedagogical methods. Our hope is that this editorial will help highlight several best practices and common issues that were associated with classroom-based, group writing exercises.

The review article written by the students is meant to represent a complete synthesis of course information, meaning we devote significant in-class and out-of-class time to this effort. In *Mechanobiology*, students begin the first class with a read of Schwartz's "The importance of stupidity in scientific research" [5], which typically sets a tone to promote discovery in the class, encouraging students to dive deep in the literature, to be less afraid of the unknown, and to be more willing to discuss ideas openly. While the course content focuses on broad and evolving topics like "Emergent Behavior" or "Signaling Pathway Crosstalk," we purposefully do not use exams for student assessment, and instead assign progress milestones that help us achieve a publication goal. Similarly, in *CV BME and Imaging*, students read "Whitesides' Group: Writing a Paper" that discusses the paper organization, the outline, and the need to highlight an overall purpose [6]. These aspects help both in writing the review paper and in critically assessing the current literature. With this approach, we set aside large portions of the class time for group editing and discussion (up to 20% or 30%), while still retaining a focus on integrating

relevant course information into the manuscript. Indeed, our writing process is often a great way to introduce key concepts, increase understanding, and promote peer-to-peer teaching.

A most recent review article, illustrating the product of this process, is included in this Education Issue of JBME, titled "Computational Fluid Dynamics of Vascular Disease in Animal Models" [7]. The manuscript was conceived of and written by 15 Purdue University graduate students over four months during the spring of 2017. The students collectively decided on a topic, broke up into different small groups, and assigned authorship among themselves. The students then setup an online Google Docs system to share the literature, outlines, and drafts of the article. Given that this article is over 8000 words and includes three tables, six figures, and 128 references, the final product is indeed a comprehensive review. The students were also given the opportunity to participate in the full publication process, including editing the initial submission and responding to reviewer critiques, which provided insight into how peers, reviewers, and editors evaluate and help to improve manuscript quality. Overall, the feedback from students indicated the first initial excitement for the prospect of developing a publication-quality manuscript, but also that the opportunity to participate in the publication process was challenging yet rewarding.

One consistent theme we emphasize to students is the need to synthesize previous work to form a clear perspective and a new, well-informed opinion that is conveyed in the review article. Creation of a review that is simply a laundry list documenting related publications in our view only provides a cursory assessment of the literature found using common search engines, and typically results in a final product that is both tedious and uninteresting for the reader. Thus, we aimed to help students carefully extract insights and conclusions from the literature in order to identify critical gaps in knowledge, while also highlighting opportunities for future studies that would lead to new basic science understanding or translational research. Because of the high standards needed for publication, several of our attempts at paper writing within the constructs of a course have failed to achieve publication-worthy manuscripts. While disappointing in some respects, these failed attempts are often just as valuable to the students as they show what minimum bar should be reached before submission and publication.

An additional idea we emphasize is that the students should not write to satisfy the (local) goals or requirements of their peers or of the instructor. Instead, we talk about the need to satisfy a worldwide audience of interested readers and hypercritical reviewers, which typically and rapidly elevates the quality of the student's work. Because the students and instructors are often not leading experts in the chosen subtopic, we are challenged to

ensure that a comprehensive and in-depth review is made of a topic within a reasonable scope. While we certainly recognize that a group of student authors may produce a less-than-authoritative review of a subject without considerable effort, we would argue that these younger researchers bring a fresh perspective to a field, and often produce a less biased review since they have not been introduced to general orthodoxy in the field. In this way, the goal is to produce an unbiased review of the literature that will hold up to scrutiny, while still providing new insight to the reader.

A first good step is to get “buy in” from all students interested in contributing to a review. We found that student interest can be piqued through the process of collectively deciding on the manuscript topic, structure, and content. One useful strategy is to provide a general topic and then have each student create a title and outline. Class discussion about these multiple outlines can then be used to combine the best aspects of each in order to create a mutually agreed upon final version. This sets the tone for the students to claim increased creative and intellectual ownership. Another strategy we have used is to first let students pitch their own topic ideas, at the cost of increased discussion time required to focus typically disparate ideas around a common theme, or to allow best ideas to emerge. Once the writing process begins, we have also focused extensively on the inclusion and creation of informative figures, tables, and schematics. Some of these are originals created by the students, and others are reproductions or adapted from seminal papers in the field. Overall, a detailed outline, clear figures, and informative schematics created by students are all important for creation of a quality review paper. Throughout the topic selection process, we were mindful of potential journals that might be willing to publish our manuscript. Occasionally, we have engaged with potential editors early on to pitch an idea by emailing a draft title and abstract. When the response has been positive, this has helped the class target a specific audience. However, we strive to remain mindful of not influencing the class’s internal selection process of topics, content, or journals. Along these lines, we have not always shared to editors that students in a course were writing the paper. While our approach is perhaps overly cautious, we did so to ensure that we received critical, unbiased reviews that we could use to improve the final product.

We have implemented strategies to resolve practical issues of author inclusion. The ideal number of authors depends on class size, students’ interests, and expectations for contributions. We typically begin each course with 1–2 class sessions dedicated to a discussion about authorship. Specifically, we discuss the importance of authorship, the major criteria for authorship, and possible steps or strategies for resolving authorship disputes [8]. The students then read a series of example scenarios describing authorship issues, discuss these within a small group, and decide among themselves who qualifies for authorship and why. This active learning experience is useful not only for the class review paper, but for the way students think of authorship throughout their research careers. Additionally, unlike most homework or projects in a course, contribution to a peer-reviewed and published article is a privilege that requires the students to be truly invested in the quality of the final product. We have occasionally offered alternative, personal writing projects to give students who are not interested other options, which helps to avoid subsequent issues regarding students who contribute little to the final manuscript.

We have also tried to provide creative solutions to resolve practical issues of author order. One strategy that has proven valuable is to identify a group of top students who are willing to serve as small group leaders, keep others on schedule, and “champion” the paper to a final product. In return, these group leaders have been

listed as co-first authors to designate their elevated role. Breaking up a larger group of authors is facilitated through online team-maker tools (e.g., CATME) that can assign students to different teams based on interests, schedules, gender, or any number of other factors deemed important. Some groups have worked well together in an egalitarian structure, while others benefit from a clearly designated leader. Another strategy has been to allow students to propose their own fun and competitive process to assign a first author who champions the paper. In one publication on signaling pathways involved in *Mechanostasis in Apoptosis and Medicine* [3], first authorship was determined by a haiku writing competition that was judged by three unbiased faculty members. The winning haiku was: “sensing outside force,/a cell shifts toward life or death./But which path to take?” Additional competitions have involved friendly sporting events (cornhole) or potluck-style cookouts (winning dish: roasted pork loin). These activities provided additional team building and camaraderie that likely helped to improve the quality of the manuscript and writing experience.

We found that students are, in general, hesitant to be hypercritical of other students’ writing. Specific encouragement was needed to get students to make significant edits to their own text and others, and this occasionally led to conflict between students, making open and honest communication key. Without this feedback, the manuscripts did not evolve and improve, as students were hesitant to thoroughly rework large sections. The use of shared online documents was very beneficial when multiple students were writing and editing at the same time (i.e., Google Docs, Dropbox, OneDrive). This also helped us as instructors identify who was contributing in a meaningful way to the editing processes, both before the initial submission and when responding to review comments. Indeed, helping students transition to a role that provides critical feedback is key to their independent growth as researchers while also improving the final product. As a related point, we occasionally faced difficulties in writing style and quality from non-native English speakers [9]. In these instances, we often found teaming up native and non-native speakers worked well to enable rapid advancement and inclusion of key ideas, while also allowing for a first filter to improve the writing quality overall.

Over multiple years, we have acquired students’ feedback on different aspects of the group assignment by completing a questionnaire at the conclusion of the project [10]. One student commented, “It was challenging to meet everyone’s idea of how a certain section should be written because there were so many writers.” When asked what aspects of the assignment were beneficial, students wrote that, “This assignment helped me learn how to collaborate among a large group of authors and compile everyone’s written contributions,” while another student commented that, “Answering reviewer comments was useful because it gave me a better idea of what is involved in the review process.” Despite the challenging nature of group writing assignments, the students reported that their understanding of the steps involved in the publication process improved, and this is probably the most important learning objective associated with this effort.

In summary, this editorial describes strategies that we have found helpful when writing a review paper with students as part of a graduate-level elective engineering class. Ultimately, we hope the strategies detailed above will help other engineering faculty who may be considering something similar in one of their graduate courses. While certainly not possible in every situation, writing a review paper with a group of motivated students is an innovative teaching practice that has the potential to be a beneficial

and rewarding experience to both students and instructors, while also creating a product that contributes to the fields of bioengineering and biomechanics.

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