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Physics in progress: teaching writing through a mock journal for authentic practice in technical writing

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Abstract

How can students in science and engineering fields obtain authentic practice in technical writing? This paper presents the author's experience instructing a writing-intensive experimental physics class structured as a mock journal entitled *Physics in Progress*. Offered in an intensive three-week format, the course centered on the students' creation of three 'rapid communication' contributions and one 'scientific article.' Students engaged in the peer review process, writing referee reports and even issuing editorial decisions on the acceptance of their peers work to the journal. This paper will discuss the successes and pitfalls of the course structure, steps that could be taken to mitigate the workload overhead of coordinating the peer review process, and the impact of the course structure on student motivation. Overall, the students' increased identification as scientists raised the stakes of instruction in experimental methods, laboratory and publishing ethics, and technical writing. This increase in identification as a professional scientist or engineer helps the students to gain authentic practice in these skills in a controlled environment and build their confidence for when these skills are needed in their future careers. The publicly available end product of the course, now published online as *Physics in Progress issue 1*, served as a motivating factor and now serves as a time capsule containing writing artifacts that students take pride in and can share in portfolios or as otherwise appropriate.

Introduction

At what point does one cease to be an undergraduate science student and begin to be a scientist? This is a difficult question to answer because it is not directly related to quantifiable course outcomes like one's ability to solve Maxwell's equations for a set of boundary conditions. Rather, becoming a scientist is a matter of formation: an initiation into habits of thinking and practice that are constitutive of a 'good scientist.' This sort of outcome is not performance based: being an insightful theorist involves more than performing solutions to canonical problems, and being a capable experimentalist involves more than performing a list of carefully procedured canonical experiments. Rather, the *raison d'etre* of the technical outcomes in technical coursework is based on an idea of habituation: the practice of certain canonical problems in a certain collection of subjects is supposed to habituate the student into a certain way of thinking that we think constitutive of a physicist, chemist, or other flavor of scientist. But science also ventures out into the unknown, past the canonical problems and the canonical experiments, and so students need to be formed in ways of handling these more ambiguous situations where right course of action is not clearly defined. Many undergraduate science curricula include opportunities for such formation, often in advanced laboratory courses or capstone/senior thesis coursework. Assessment of these formational outcomes is possible, but not as straightforward as for technical outcomes. The question then is one of finding pedagogical techniques that actually make a formational impact on students and concrete engagement with which are clearly assessable.

This paper describes a course recently taught at a liberal arts institution (primarily undergraduate) in the great lakes region: a senior-level advanced laboratory class, experimental physics. I taught the course as structured around a mock scientific journal, which the students named *Physics in Progress* [1]. Students created writing artifacts in a journal format (several rapid communications and an original article), they gave peer-reviews, and had editorial control over which articles were posted publicly at the end of the course. My initial reasoning for structuring the course in this way was simply that it seemed like a fun experience for the students. However, in the time since, I have found this structure resonates strongly with two current approaches to pedagogy: open pedagogy and character-based pedagogy as well as providing a context where formational outcomes are rendered assessable.

Open pedagogy refers to a broad variety of teaching methods, but the common theme is the production of open access materials [2]. One of the major themes of the open access movement is the production of knowledge as a communal effort, and as a result pedagogy around creating open access materials often emphasizes building habits that allow healthy engagement in the social construction of knowledge. This might involve the remixing of open access course educational resources or the creation of new content that will be openly available, but one common feature is a moving away from disposable assignments [3]. That is, student work is posted publicly for engagement of future students or others who may be interested. This can take many formats, but course journals or school-wide student journals are one open pedagogical method which is growing in popularity [4]. A focus on the communal creation of content also involves giving students more authority over the publishing process in terms of peer-review and content moderation. Engaging students in formal peer review not only constitutes training on best practices for future engagement in the scientific peer review process but also gives a first-hand experience with the shortcomings and biases of the process [5], [6]. The socially and experientially rich situations which this method naturally creates indicates that it would pair well courses with primarily formational outcomes. These include advanced laboratory classes such as the context I will describe in this paper, but would also naturally apply to contexts such as course-based undergraduate research experiences (CUREs) [7], [8] or senior capstone experiences. The situations created by open-pedagogy also dovetail nicely with character-based pedagogy.

As already discussed, education is primarily a formational endeavor. However, it can be easy to focus only on formation in a discipline and forget that a 'good physicist,' for example, is simply a specification of the category 'good person.' As a result, a renewed interest is emerging in pedagogical methods that support student formation in dispositions or habits constitutive of being a good person *qua* physicist (or engineer, chemist, etc.). One of the most succinct resources which I have found for implementation of this character- or virtues-based pedagogy is a list of seven principles for cultivating virtue in the university [9]. These principles, reinforced by current psychological research, provide much of my current justification of the pedagogical decisions relating to the mock journal, so I will list them at length. Once a virtue has been identified, formation can be encouraged by giving students opportunities for 1) habituation through authentic practice, 2) reflection on personal experience, 3) engagement with virtuous exemplars, 4) dialogue that increases virtue literacy, 5) awareness of situational variables affecting the exercise of a virtue, 6) moral reminders, and 7) friendships of mutual accountability. The mock-journal allows students to step into the role of scientist and practice what it means to do science. In the process, this practice is supported by course structures and activities which reinforce this practice by means of the other six principles.

The remainder of this paper will be organized as follows. In the first section, I will introduce the course structure in terms of the major outcomes, activities, and how the mock-journal is structured into the course. In the following section, I will discuss several considerations relevant to the mock-journal format, including considerations of instructor workload as well as successes and pitfalls encountered in the first implementation.

Course structure

The course in which the mock-journal was implemented, physics 4120: experimental physics at Carthage College, is an upper-level laboratory class which exposes students to a more open-ended laboratory experience and is the main writing-intensive course in the physics curriculum. For context, this course is offered in a 3-week intensive format over the course of Carthage's January term (J-term). In J-term, student life is less active as only a portion of the student body is on campus. In addition, since students can only register for a single J-term course, a more intense focus on the course can be expected.

The course was structured around the following broad student outcomes:

- Be able to function effectively and independently in a self-directed laboratory environment both as an individual and on a team.
- Be able to measure and propagate experimental uncertainties and understand their value in the communication of precise scientific results.
- Be able to effectively communicate and justify scientific experiments and their results in a variety of formats.
- Appreciate science as a common good and embody ethical principles for scientific communication and scholarship which uphold the efforts of the broader scientific community.

This last outcome is the immediate motivation for the mock-journal format, although the journal also supports the other three outcomes.

Primary Course activities

As a writing intensive laboratory course, the primary course activities consisted of labs and the production of writing artifacts. Over the course of the 3 week term, students explored six laboratory experiments. These were primarily in teams, though students were required to work individually on at least one lab. These labs formed the basis for the writing artifacts of the course, which were three rapid communications and one original article. Rapid communications were two-pages in length and designed to mimic the format of common rapid communication journals, e.g. *Phys. Rev. Letters*. These served as the primary lab reports. Throughout the course, students were preparing a longer-format piece of writing, styled as an original article. Peer review of writing took the form of generating referee reports in the mock-journal process and students also received feedback on each writing assignment from the instructor.

The bulk of class time (3 hours Monday-Friday) was devoted to lab time, but some time was reserved for instruction. Technical instruction included estimation of experimental uncertainties and the propagation of error, least-squares regression, other data analysis techniques (e.g. principal component analysis), and the use of LaTeX. In addition, class discussion on practical virtues pertinent to practice in a scientific setting. One such session was on the integral parts of prudence to give students a toolbox for decision making in the lab setting, while another session focused on justice and temperance as related to scientific communication and the publishing/peer review process. After every rapid communication was graded the instructional period was used for a debrief discussion on good and bad patterns of writing that I found across submissions.

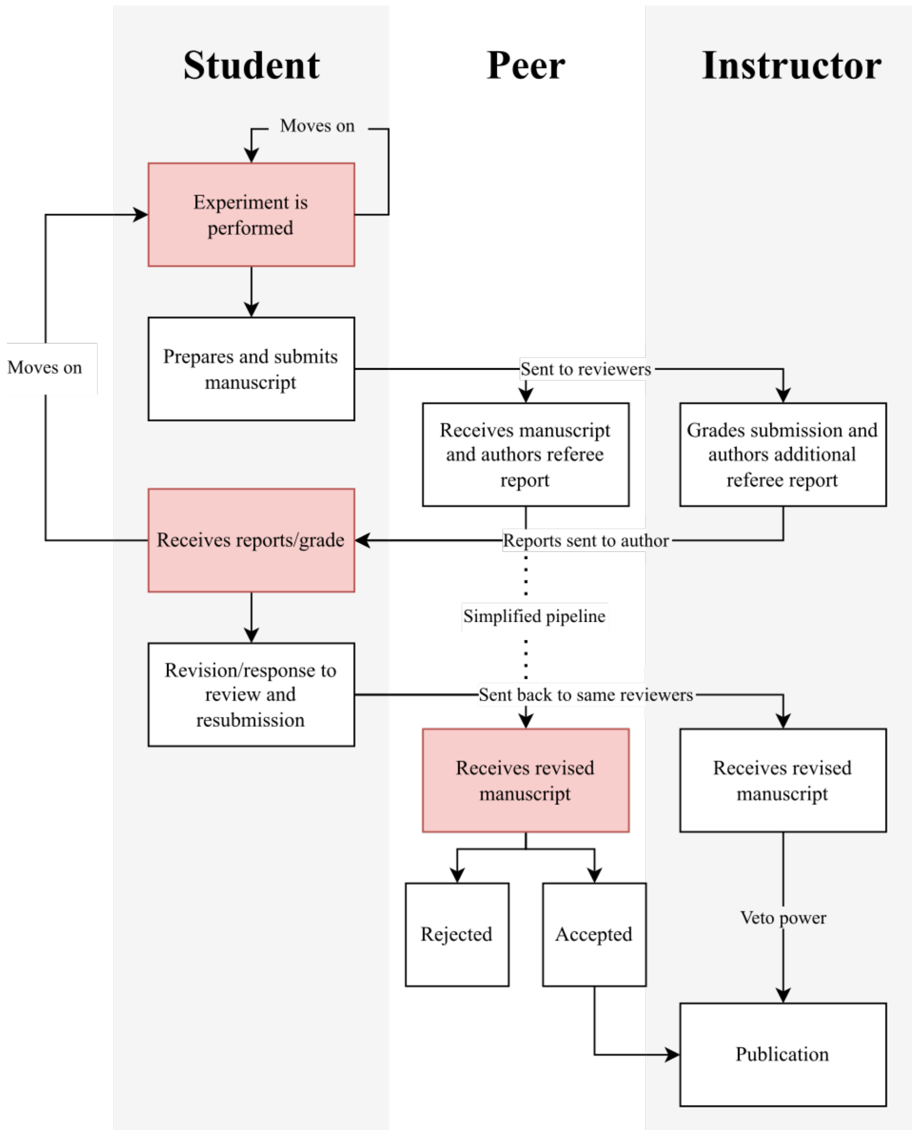

Figure 1: A flowchart of the mock-scientific publishing process, demonstrating the role of each set of actors in the process. An experiment performed is by no means guaranteed to reach publication; multivalent stages, whether to write a manuscript, whether to revise and pursue publication or the reviewers publication decision may all terminate the process prior to publication.

Mock Journal Structure

The mock journal structure consisted primarily in the following activities:

- Preparing and submitting 3 rapid communications and 1 original article to the journal.
- Peer review: for each round of submissions, students prepared a referee report on a classmate's submission. I played the role of the infamous "reviewer no. 2," preparing a second referee report.

- Revision and resubmission: students were encouraged to revise their contributions and respond to reviewer comments, resubmitting their manuscripts.
- Editing day: students gathered in committees to determine which submissions would be published.

A summary of this structure and the publishing process can be found in figure 1. In this first iteration of the course, revision of manuscripts was not required, this is demonstrated by the dashed line.

Stakes: Grades in the course primarily consisted of the writing artifacts. Referee reports were also loosely graded for quality control (largely just satisfactory/unsatisfactory). The remainder of the course grade was determined by less traditional components. The following three course grade components were incorporated to provide stakes for the students actions in the mock-journal context:

1. The publication decision of the peer reviewer was factored into writing artifact grades.
2. Publishing: a token amount of the grade was earned by two contributions being published. A limit of two contributions on any single lab activity was enforced, with committees of students choosing the two strongest (anonymized) submissions on editing day.
3. Community standards: a flat 5 points applied to the entire class reflecting the reputation of the journal. Unethical behavior, lax reviews (accepting manuscripts that were major flaws), overly harsh review, failure to report conflicts of interest, etc. resulted in reductions.

The first two render students accountable to their peers for the quality of their work and give students the opportunity to engage ethically or unethically in the publishing process. The community standards grade allowed me as an instructor to punish and discourage unethical behavior. These also serve to enhance the authenticity of the exercise by providing real consequences to the students' actions.

These stakes operationalize several principles of virtue-based education discussed in the introduction [9]. The power of students over their peers' grades gives real weight to their peers' feedback, and creates relationships of mutual accountability. The publishing incentive mimics the 'publish or perish' pressure faced in academia and introduces complex ethical decisions to the review process, giving students a chance to reflect on situational variables. Lastly, the community standards incentive serves as a moral reminder to students of the consequences of unethical behavior.

Authenticity: The role-playing dimension of the mock journal is an important factor in the effect that it has on students. In order to support this end, I developed the following infrastructure to lend a feeling of authenticity to the journal: 1) A journal website where students would find information for authors, reviewers, and a submission portal [1]. This is also where the published contributions were publicly posted at the end of the course (with student consent). 2) A database management system for manuscripts and peer reviews: submissions were powered by Google forms, allowing all manuscript data to be managed in Google sheets. 3) Emails from the editor: at all stages (submission, assignment of referees, notification of decision/referee comments on a submission, final publication decisions, etc.) students were contacted by email from the "Editor-in-chief of *Physics in Progress*" (i.e. me, the instructor). Templates and mail merges were used to simplify this process; for more information see the instructor workload management section. From student feedback, this infrastructure seems to have the desired effect. Students were surprised to see their own work featured on a 'professional-looking' website and official tone of the emails to from the editor helped them to see themselves as real scientists.

Discussion

Instructor workload management

The student workload was high, but so was the instructor workload. At the end of the day, students are submitting three writing assignments and one scaffolded major writing project in a three-week period, all of which need to be graded and given feedback. With a sufficiently detailed rubric, a teaching assistant may be able to grade the assignments. However, I would suggest that the feedback an instructor can give on the writing assignments is invaluable and the instructor should read and give feedback in the form of a second referee report.

The mock-journal structure additionally comes with its own logistics workload, including:

- Assigning peer reviewers to minimize conflicts of interest,
- Sending emails assigning peer reviewers,
- Sending emails notifying authors of the results of the peer review process,
- Creating official-looking proofs of the accepted manuscripts, and
- Creating the publicly posted website.

The logistics workload, however, is heavily dependent on the use of appropriate information systems. Google forms was used to collect submissions, resulting in two databases: one for manuscripts and one for peer reviews. With appropriate usage of spreadsheet software, a significant amount of the management of the database can be automated (cf. resources section). The communications prong of this logistics workload is best handled via **mail merge** (a term that I was not initially familiar with). When you receive personalized marketing emails, this is how it is done. A template is made with some fields which are to be customized. A spreadsheet is then prepared with the corresponding fields as columns and each recipient as a row. A mail merge software then fills in the template with the information and sends the resulting emails. Outlook has a feature for this if your organization uses Microsoft suite. My organization uses the Google suite, and so I used the "yet another mail merge" extension. The email templates (cf. resources section) were prepared using the following webpage as a starting point [10].

If I had more advanced LaTeX knowledge, the proof preparation may be reducible to defining an appropriate LaTeX style template. However, as a stopgap I designed a document preamble and used a similar mail merge-type solution to fill in specific fields (e.g. title, abstract, author name, etc.).

When I initially created the publicly posted site, I used Google sites. This required manual entry of data for each page, and so was not well suited to this application. I have since created a solution that leverages the manuscript database. A MATLAB script is used to transform the database into markdown files which a static site generator (Jekyll) uses to generate webpages (cf. resources section). Jekyll is integrated with Github pages, which provides a free hosting service as well. The result is a professional-looking website with significantly less workload than manual entry on Google sites.

Successes

During the course, I noticed several positive effects that the journal was having on students. The primary effect that was immediately obvious was increased motivation for writing among the students. For a three-week course, this course involved a large writing workload as well as the data preparation work required for technical writing. However, while students often expressed surprise or commiseration, they often verbally expressed an appreciation of the writing focus of the course. The detailed feedback generated by the referee reports resulted in rapid improvement in the writing quality as the course progressed, of which improvement the students were consciously aware. These considerations map well onto the self-determination theory of motivation, in which autonomy, competency, and social connection are thought to lead to greater intrinsic motivation [11]. The selection of topics as well as the perceived student control over the editorial process produce a sense of autonomy while the rapid iteration of the feedback cycle produces a perception of competence. The social aspects of the peer-review process and reflection on virtuous engagement with a community of practice helped to foster a sense of social connectedness.

The course structure was well received by students and seems to have supported the desired outcomes. A final survey is summarized in table 1. From the written feedback section, a common theme was that the mock journal structure was directly related to the agreement to many of the other statements. Student feedback indicated that the anticipation of their work being publicly available and looking official motivated them to produce work that they were proud of and to improve their writing from one assignment to the next. These responses also indicated that the role-playing aspect and the peer-review process helped them to identify as a scientist and changed how they understand the scientific process.

Table 1: End of semester student feedback results

Statement	**Agree or strongly agree**
I feel more independent in a laboratory/research setting than I did at the beginning of this course.	15/17
This course helped me to improve my writing skills.	16/17
I created at least one piece of writing this semester that I feel proud of.	15/17
This course changed how I look at the scientific process.	13/17
I feel more confident identifying as a scientist than I did at the start of the course.	13/17
I enjoyed the mock journal aspect of this course.	12/17*

*High concentration (10/17) in strongly agree

In the time since the course has finished, I have noticed that the students remain proud of the work that they produced in the course. Our department capstone experience involves students creating a portfolio of the work they are proud of and showcases their skills to potential future employers. I was pleased to see that contributions to *Physics in Progress* made frequent appearances in the senior portfolios this year. The open access and public nature of the final product has led to diverse opportunities for students to showcase the work produced in the course instead of simply being lost to a learning management system archive.

Another major fruit of the mock journal structure was that it created an opportunity for rich reflection on a variety of nuanced topics related to the practice of science. Three major principles for cultivating virtue in an instructional setting which are operative here include habituation through authentic practice and reflection on personal experience. As students progressed through the course, discussions were held on topics such as 1) principles of decision making in a laboratory context, 2) duties to the scientific community and how this affects scientific communication and peer-review, 3) conflicts of interests and other negative incentive structures which can lead to unethical behavior, among others. Students were able to relate these topics to their immediate experience in the laboratory, writing, and mock-journal processes and to implement them in the following iterations of each. The grade stakes of the student interactions made discussions of ethics hit close to home as students witnessed firsthand the consequences of a negative or lax review as well as the temptation of a competitive outlook on the publishing process.

In summary, the mock-journal produced many intangible positive effects in the students. It helped students to experience firsthand many of the nuanced decisions involved in the practice of science. This model fit especially well in a laboratory class where the relationship between science communication and the 'doing' of science was immediately clear.

Pitfalls

The main pitfall of the course revolved around the original article. First, the original article scaffolding was poorly paced. I initially thought that it would be useful to have students begin an outline after receiving feedback on their first rapid communication, but this was too late as half the course had already passed by. The result was that the rough and final drafts came at times when students were already swamped with writing. This lead to poor quality of many of the original articles. Several of the students with preexisting intrinsic motivation worked diligently on the article for their own personal reasons, but these were exceptions and not the rule. More care should be taken to pace the original article deliverables to even out the workload, and include class time for immediate feedback in the early stages. Additionally, more structure that can be provided to the scaffolding deliverables would allow more students to stay on track with the assignment.

Second, allowing literature reviews led to significant issues. Students chose this option (as opposed to a more detailed write-up on a lab) because they incorrectly perceived it to be a lower workload. I had a significant issue with AI plagiarism in many of these literature reviews, and I believe that this was primarily a time-management issue related to the pacing problem discussed above. There were one or two excellent literature reviews, so I do not know if I will outright disallow them in the future. I think that with better scaffolding and oversight in the outlining/drafting stages, these issues could be remedied. By more stringent requirements (e.g. annotated bibliography at the outlining stage) at each stage, AI use could be mitigated and the path of least resistance could be steered toward the experimental option.

A better model for the original article would be to strengthen the experimental option. To reinforce the experimental outcomes, the original article could require students to design an original experiment (based on extremely loose descriptions) and execute it. The outlining stage could then be used to design science outcomes and the draft stage could involve a more detailed set of methods and anticipated results before executing the experiment in the later stages of the course. This format would allow feedback on both laboratory related skills and writing simultaneously.

The other main pitfall of the experience was the publishing process. In the editing day stage, some of the manuscripts chosen for publication were still of unacceptable quality. These received the publication grade points but were not posted. In retrospect, this may have been caused by improper incentives being applied to the revision and resubmission process. In the future, to be considered for final publication and to receive those grade points, revisions and responses to comments will be required. It may be worthwhile to reserve a portion of the artifact grade for responses to comments to more strongly incentivize revision.

Application to other institutional environments

Some aspects of this course structure are naturally peculiar to the institutional context; the serial lab-based nature of the course, the three-week format, and the class size could all affect the implementation of the mock-journal structure. The three-week timeline and serial lab structure would be the easiest aspects to change. A one- or two-semester course would naturally benefit from both a more relaxed pacing as well as opportunities for producing more than three rapid communications. Additionally, a longer timeline could render the scientific article more achievable. In this course, the experiments were isolated, and students only prepared manuscripts on half of the labs performed. However, the rapid communication and article distinction could be naturally extended to a class structure centered around a single long project if it permits division into discrete stages. Rapid communications could then serve as interim reports which then are collated into a cohesive article as a final report.

The more difficult question for extension would be dealing with larger class sizes. With proper information systems as described previously (cf. resources section), the logistics workload would easily scale to larger class sizes and could be reliably delegated to teaching assistants. However, the grading and workload (as in any writing intensive course) would be more difficult to scale. Preparation of more detailed rubrics could allow teaching assistants to grade the writing artifacts, but the instructor should probably still prepare a referee report (which in my opinion was quicker than the grading). In the absence of teaching assistants it may become necessary to render the first submission grade as entirely in the hands of multiple peer reviewers (e.g. through a calibrated peer review process [12]), although this would probably affect the authenticity of the exercise as mapping to the scientific peer-review process.

Conclusion

In conclusion, I consider *Physics in Progress,* volume 1 issue 1 to be a successful first implementation. The mock journal format consisted primarily of submission of manuscripts, a formal peer-review process, peer selection of manuscripts for publication, and the eventual public posting of manuscripts. This format successfully reinforced the formational outcomes of the advanced laboratory course where it was implemented. The permanence of the writing artifacts produced in the course among other factors produced motivation in students which was able to sustain them through a heavy writing workload. The role-playing aspect helped students to form an identity as scientists and gave rich opportunities for reflection on several nuanced aspects of professional practice as a scientist. A supporting infrastructure (made publicly available) was developed which reduces the instructor workload overhead of the mock journal format, streamlining implementation in future offerings of the course.

Resources

A repository of course resources can be found at [13]. It contains course materials such as:

1. The course syllabus and schedule.
2. The referee report template shared with students to give a uniform structure and minimal acceptable amount of feedback.
3. The rubric used to grade the rapid communications.

Additionally, it contains some of the database infrastructure used to streamline the journal workflow, including:

1. Example google forms for all submissions.
2. An example google sheet where the submission data lands and is processed
3. Email templates for the major email campaigns associated with the course

The journal website is hosted on Github pages, and as such all the files are publicly available at the repository used to generate the site [14]. If you would like to use this model to generate your own journal website, you can fork the "template" branch of the repository and follow the instructions in the corresponding README document.

All resources are licensed under the Creative Commons Attribution Non-commercial Share-alike 4.0 International license [15].

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