

Implementation of Peer Review to Enhance Written and Visual Communication Learning in Bioengineering Capstone Reports

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In addition to technical skill development, engineering undergraduate curricula must also foster development of effective communication skills. The capstone report often plays an instrumental role in this development, as it comprises both the final assessment of student communication performance and it is the most significant opportunity for active learning of in-discipline communication skills. Peer review has been proposed as an ideal means to provide students with much-needed formative feedback.¹⁻³ In addition, peer review has the potential to increase student interpersonal communication skills and metacognition, provided that the review activity is structured to encourage constructive contributions and reflection.

In this paper, we build on our previous work-in-progress⁴ describing the implementation of a peer review strategy integrated throughout the year-long capstone experience that allows students to obtain formative feedback and build transferable communication skills and insights. Students completed a workshop series of scaffolded communication critique, small-group formative peer review, and reflection. First, students were guided to collaborate as a class to generate rubric for sections of the capstone report, as well as guidelines for constructive and effective peer feedback. Next, students used these codes to provide feedback in small groups. When students submitted their revised draft, they included a cover letter describing their reflection on peer feedback and the changes they made due to peer review.

The novelty of our specific approach to peer review lies in the combination of three qualities:

- 1) The degree of student contribution to setting standards for both effective writing and effective critique. This gives students ownership and a stake in these standards, as well as providing scaffolding for critical thought about formal and casual professional communication.
- 2) The degree of scaffolding for student critique. A criticism of peer review is that student reviewers can be unconstructive. Our approach includes a structure to help students stay focused and provide helpful critiques.
- 3) The degree of reflection required of students toward learning, retaining, and transferring their in-workshop learning.

Our approach was evaluated by student surveys including both quantitative and qualitative assessment, and instructor analysis of cover letters describing the impact of peer review. Students reported that 1) discussing what makes good Introduction and Methods sections helped clarify their thoughts and/or approach, 2) obtaining feedback helped or will help them improve their drafts, and 3) providing feedback to others helped students clarify their own thoughts/approach to writing. Results also indicate that peer review increased student preparedness and confidence in their ability to write an effective report. Students reported that hearing multiple points of view in a low-stakes environment was very helpful.

By engaging bioengineering students in this way, we enrich their learning experience by providing tools they can use toward capstone report performance, as well as communication, self-regulation, and reflection skills that can be transferred toward future professional challenges.

Background and Rationale

The use of peer feedback toward formative assessment, hereafter referred to as *peer review*, has long been established as a “best practice” to increase the value of students’ writing education.⁵⁻⁷ Peer review has been consistently shown to increase students’ writing performance as well as their learning retention.^{8,9} Peer review has been shown to be an especially effective learning for English-language learners, even when their peer partners are also non-native speakers of English.^{10,11}

Students’ consistent performance increase is generally attributed to a cluster of interrelated practical and cognitive factors. Foremost, given the limited time that an instructor has available for formative review of student writing (particularly in writing-across-the-curriculum designs), peer review effectively increases a student’s opportunities to receive timely feedback to inform revisions.^{2,6} Reviews across a breadth of research suggest that in higher education settings, the effect of peer feedback upon a student’s work is equivalent to the feedback of the instructor.¹ Substantive revision is a key practice of experts that we must often scaffold in students, and peer review serves as an organizing circumstance for such revisions with minimal investment of class time for turnaround.^{8,11,12}

Curricular economy belies a deeper factor for the consistent gains that students make through peer review activities. In addition to increasing feedback and revision cycles, peer review activities increase reflection around writing in ways that iterations do not. Providing meaningful feedback to a peer is an intensely metacognitive process that requires students to clarify and articulate their own writing values and solve complex problems of meaning-making and expression.^{6,8,13-15} Previous studies have shown that the true beneficiary of peer review is not the receiver, but the reviewer,¹³ and the quality of a student’s reviews of peer work is positively correlated with the increase in quality of the student’s own work.¹⁵

One of the major perceived drawbacks of peer review is that students and faculty alike often express skepticism that student feedback will be of sufficiently high quality and validity to positively inform one another’s writing performance.^{1-3,5,16} This drawback has been deeply undermined by a number of studies and meta-reviews over the last thirty years, which show student feedback is on average as valid and reliable as that of an instructor (for examples, see refs [1, 3, 5]). The breadth of literature surrounding peer review validity offers the practitioner a number of significant insights. First, better and more reliable feedback occurs when more students review a given piece of writing (for example, see ref [2]). Second, student assessments are more reliable and valid when students are given a structure upon which to evaluate, such as a rubric or coaching (for examples, see refs [8,17]).

Peer review has been proposed as an activity that has particularly high potential to support writing-across-the-curriculum in STEM disciplines, particularly engineering.^{7,17,18} Certainly its relatively fast turnover of feedback is a good match to the unforgiving density of most engineering classes, and its prudent use of instructor time is imperative given the increasing use of large-enrollment classes in engineering disciplines. Its particular value to English-language learners makes it an ideal pedagogy for today’s multicultural engineering student body. And peer review has been suggested as an activity that aids transfer of knowledge to new situations, which has been identified as a critical issue in engineering education.¹⁹ Beyond peer review’s intrinsic

pedagogical value, it is seen as highly compatible with the kinds of peer review situations that professional scientists and engineers encounter in the workplace and in academic publishing.^{20,21} Thus, peer review provides both a means to foster long-term improvement in our disciplinary community's scientific publications,²² as well as a means to add authenticity to writing assignments in order to increase student buy-in and motivation.²³

Our present work provides a history and case study of an experimental peer review design in a Bioengineering capstone course sequence. Given a one-credit allotment of instructor time toward this capstone, peer review seemed a promising way to enrich students' writing education in their capstone project report. But moreover, we believed that senior-level students who have had repeated exposure to journal and conference articles have already acquired a degree of practical expertise in our disciplinary discourse; near the conclusion of their college education, we didn't believe it appropriate or warranted to teach them writing skills from scratch. Rather, we felt that a better pedagogical approach was to help students discover and marshal their own expertise and that of their peers. In this way we might scaffold students' metacognitive use of their own experiences as readers, as well as the social supports of their peers, as these are often the primary tools that inform the writing of the professional engineer. The three most novel aspects of our design are as follows:

1. Rather than providing a rubric or evaluation form as a structure to assess peers' work, students were guided to examine their own experience as readers. They were guided to collectively decide upon the most important components of writing, toward composing a shared class rubric that expressed students' synthesized values about disciplinary writing.

This approach has very limited precedent in the literature on student writing³, and we have not been aware of a similar approach in engineering disciplinary writing. An awareness of both constructivist theories of learning and the self-determination theory of motivation inform our approach to this design.²⁴ We hypothesized that if students were involved in the creation of the assessment rubric, it would be more meaningful to them because 1) they would be more likely to buy into its content and apply it effectively to their peers' writing, and 2) they would be more likely to internalize the content of the rubric and retain it toward writing endeavors in their future careers.

2. Students were similarly guided to reflect upon their own experiences as recipients of feedback in order to articulate what helped them and what did not. From this, students were guided to form a brief behavioral charter that expressed students' collective values about collegial behaviors from both the reviewer and reviewee.

A common challenge in peer review is students' understandable social responses to the peer review process. Even in a class of seniors it is likely that students may unthinkingly give unconstructive, discouraging, or disparaging critiques; and the recipients may easily become defensive and unwilling to engage in the construction of a better written work.^{3,25} Our approach includes a structure to help students stay focused and provide helpful critiques. The principles of our design of a behavioral charter component were similar to our design of the student-generated rubric. We believed that students would buy in, internalize, and retain notions of professional and effective peer feedback if they had a leading role in constructing the guidelines.

3. Students provided feedback to one another verbally within group dialogues, in a mode that mimics artists' studio critiques and writers' workshops.

Presently, most engineering peer review is conducted out of class or online, and anonymity is often a key component (for examples, see refs [20,26]. We are not aware of many others in engineering using a discussion-based workshop approach for feedback, though this is a common structure for feedback among professional writers and artists.²⁷ Our rationale for this approach is that a broad source of dissatisfaction regarding writing feedback is that it is enacted as a mandate rather than a dialogue. Thus receiving written feedback is often educationally interchangeable with receiving instructions, and does not engage the student in an active construction of writing knowledge. By contrast, students who worked in studio implementations have been shown to make greater gains in writing, and tend to undertake revisions that exhibit an expert's tendency toward reconceptualization rather than a novice's concern with polish.^{12,28} Students who can work in dialogue can support one another's learning.¹⁰

Capstone Workshop Series: Implementation of Peer Review

To facilitate the effective drafting of the 50-page capstone report and provide students with feedback on their writing, we implemented a peer review strategy in which each academic quarter involves workshops addressing specific components of the capstone report. Importantly, we timed the workshops to align with student progress in their project at that point (i.e. Autumn quarter workshop focused on the Introduction and Methods section, and the Winter quarter workshop focused on the Results section).

Bioengineering senior undergraduates at UW are required to complete a 2-3 quarter Capstone Design course, which supports the capstone research experience with weekly 50-minute meetings. We utilized those meetings for our workshop sessions, extending the class period as necessary

Over the past three academic years, students in our Bioengineering capstone course completed a multi-session workshop series of scaffolded communication critique, small-group formative peer review, and reflection. In Autumn quarters, students were guided to collaborate as a class to generate a class rubric for sections of the capstone report. Instructors compiled student ideas into a class rubric, which students used to guide their evaluation of their classmates' work. In subsequent sessions, students performed peer review in small groups, and then the groups reconvened as a class to share successful writing techniques. Finally, students were prompted to reflect on these successes and use them to generate ideas to improve their own work.

The details of the workshop series in three offerings are shown in Table 1. Although the overall structure of the series was consistent, we modified our approach over the years to make improvements based on student feedback and instructor observations (see Assessment section). The 2014-2015 workshops are described in more detail in previous work by the authors.⁴

Autumn Workshop Session 1 (50 min):

Generation of Standards for Effective Writing and Rubric for Capstone Draft

Objective:

Students reflect upon their own experience as readers of scientific literature in order to articulate the qualities that make effective Introduction and Methods sections.

Activation:

The facilitator led the students in discussion of their user experiences in performing a literature review for their capstone report. Prompts were presented asking students to identify what makes good Introduction and Methods sections.

Learning Activity:

In small groups, students identified qualities that made good Introduction and Methods sections. After 10 minutes of group discussion, groups reported back to the class. The instructors compiled consensus items into a master list, which was distributed to the class as a rubric. (See Appendices A-C for student-generated rubrics.)

Call To Action:

Students were asked to use the rubric as a guide when reviewing drafts.

Autumn Workshop Session(s) 2 or 2-3 (75 min or 2x50 min):

Expectations for Conduct and Useful Feedback; Peer Review in Small Groups

Objective:

Enable students to provide meaningful guided peer review of drafts.

Activation:

The instructor asked students to share prior peer review experiences to uncover what constitutes useful feedback. The class reached consensus on the following criteria for providing helpful feedback:

- 1) Always suggest something actionable (solution or improvement).
- 2) Be specific.
- 3) Be sure that reviewer feedback is clear to author (e.g., written comments are legible, verbal comments are understood by author in real-time).
- 4) Positive feedback is appreciated!

As a class, students then established rules of conduct for their peer review session:

- 1) Be kind, but constructive.
- 2) Do not edit or proofread, instead focus on reader's experience.

Learning Activity:

Students discussed each group member's draft in turn (see Table 1 for specifics). Guiding questions for authors to ask reviewers were displayed on the screen in the classroom:

- 1) What was your overall experience as you read my draft?
- 2) Could you find everything you needed?
- 3) What helped you read this draft?
- 4) What was not helpful?
- 5) Based on the dimensions of the rubric, what can I do to strengthen my draft?

Call To Action:

Students were asked to revise their drafts in light of the peer review feedback. In 2015 and 2016, instructors emphasized that students should consider not only the feedback they received, but also any successful writing strategies they observed in other students' drafts.

Winter Workshop Session 1 (50 min):

Generation of Standards for Effective Writing and Rubric for Capstone Draft

Following the general approach of the Autumn workshops, students discussed the Design and Results sections of classmates' drafts.

Spring Workshop (50 min): Design Principles in Figures

Students were led in a class discussion to identify and understand visual design principles, and then provided peer critique of capstone report figures. For more information, see work by the same authors.²⁷

Table 1. Overview of Peer Review Sessions			
	2014-2015	2015-2016	2016-2017
Total # Sessions	Autumn: 2 Winter: 1	Autumn: 3 Winter: 1	Autumn: 3 Winter: 1
# Students in Each Group	Autumn: 3 Winter: 3	Autumn: 4 Winter: 4	Autumn: 4 Winter: 4
Formation of Small Groups for Peer Review	Autumn: Groups randomly assigned by instructor. Winter: Groups assigned by instructor based on research theme (due to student request in Autumn).	Autumn and Winter: Students sign up for groups (not based on research theme or capstone track).	Autumn and Winter: Students sign up for groups, based on capstone track (research + design, or research only).
Submission and Review of Drafts	Autumn: Author brings paper copies of draft for peer reviewers. Drafts read and reviewed on same day during class (Session 2). Winter: Author uploads draft online, and instructor emails draft to peer reviewers 1 week before peer review session.	Autumn and Winter: All students upload draft online 1 week prior to peer review session. Peer reviewers download, review, and bring paper copy to next class (Sessions 2-3).	Autumn and Winter: All students bring 3 paper copies of their draft to class 1 week prior to peer review session. Peer reviewers review, and bring comments and paper copy to next class (Sessions 2-3).
Time for Discussion of Each Draft	Autumn and Winter: 10 min	Autumn and Winter: 20 min	Autumn and Winter: 20 min
Assessment of Student Experience	Autumn and Winter: Survey (Appendix IV)	Autumn: Survey (Appendix D) Winter: Cover letter submitted with revised draft describing changes made due to peer review	Autumn: Survey (Appendix D) Winter: Cover letter submitted with revised draft describing changes made due to peer review

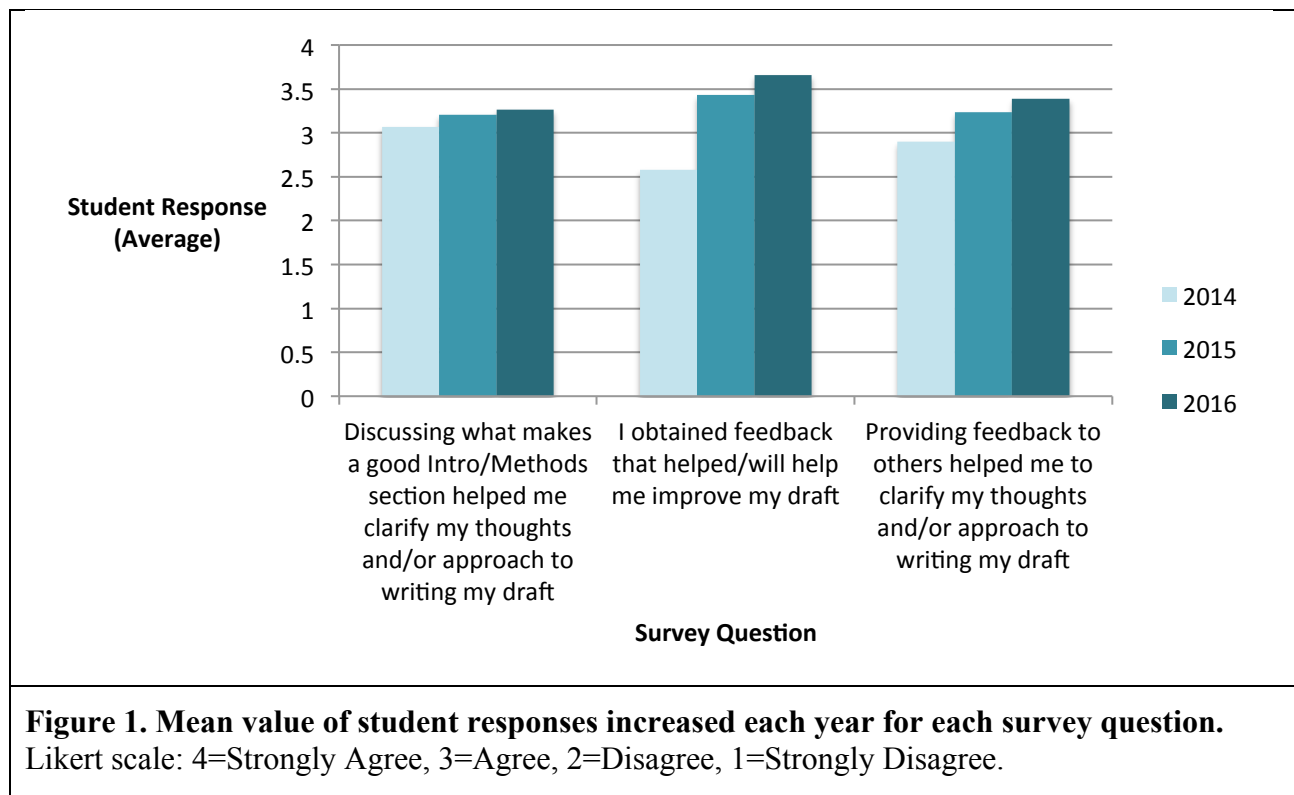
Assessment of peer review

We assessed student experience in the workshop series through surveys in Autumn quarters and short written summaries written by students in both Autumn and Winter quarters. The student summaries were submitted with the end-of quarter capstone report drafts, and were written as “cover letters” describing the changes they made to their capstone reports due to peer review.

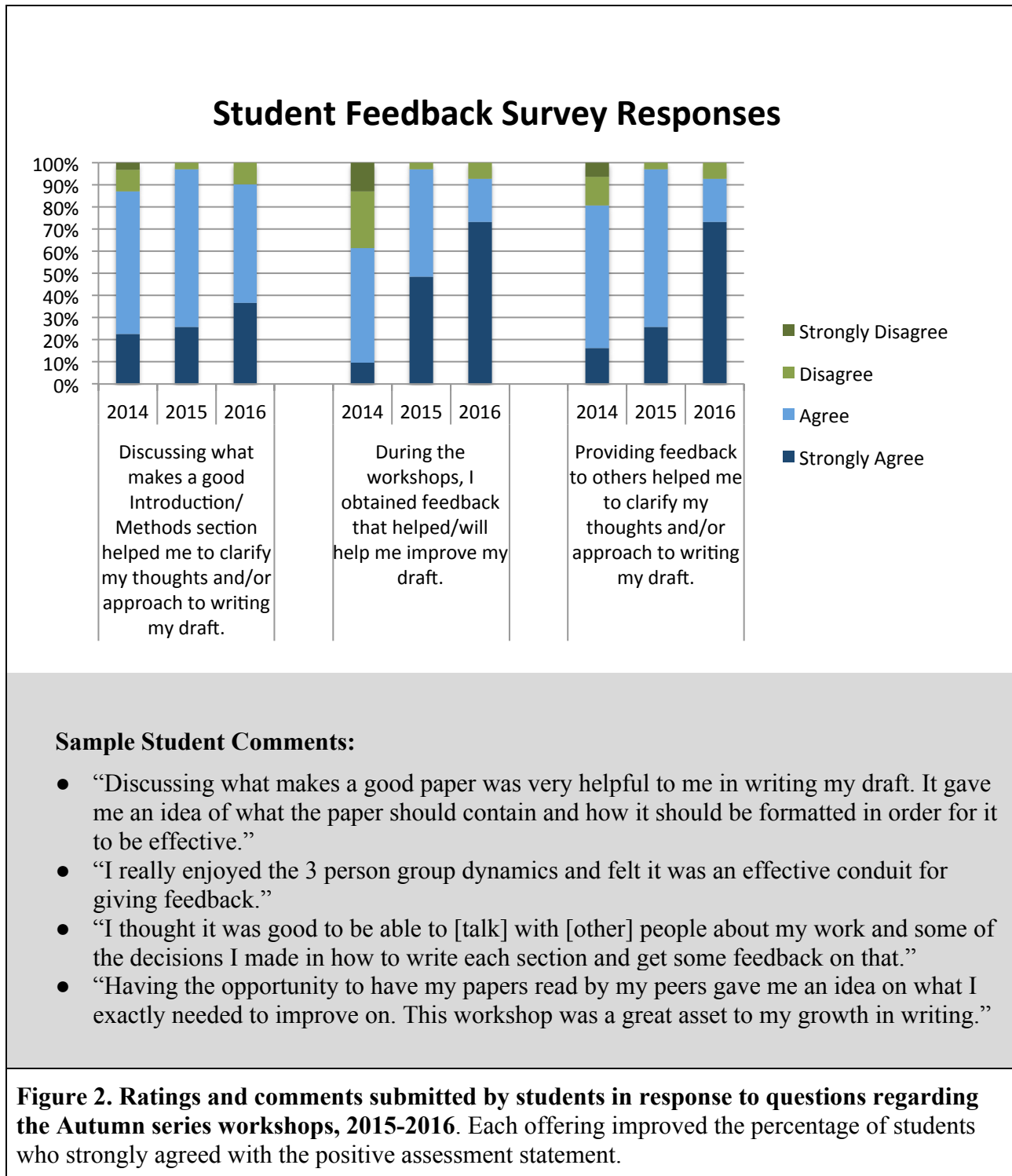
Surveys

After completion of the Autumn quarter in-class peer review workshops, students were asked to complete an anonymous survey regarding their perceptions of the workshops. Surveys were completed by 31, 36, and 41 students who attended the peer review workshop in Autumn 2014, 2015 and 2016, respectively. The survey asked students to rank their agreement with three statements about the helpfulness of peer review, and answer several questions in free response format (survey shown in Appendix D).

For the three statements regarding the helpfulness of peer review, we found that the mean value of student responses slightly increased each year for each statement (Figure 1). The mean response values regarding the helpfulness of discussing drafts were 3.1 (SD=0.7), 3.2 (SD=0.5), 3.3 (SD=0.7) in 2014, 2015, and 2016, respectively. The mean response values regarding the helpfulness of peer feedback were 2.6 (SD=0.8), 3.4 (SD=0.6), 3.7 (SD=0.6) in 2014, 2015, and 2016, respectively. The mean response values regarding providing feedback to others were 2.9 (SD=0.7), 3.2 (SD=0.5), 3.4 (SD=0.8) in 2014, 2015, and 2016, respectively.



Overall, the responses were very positive, with the majority of students responding “Agree” and “Strongly Agree” to each statement (Figure 2). The number of students who responded “Strongly Agree” increased with each offering.



Of the 108 students surveyed in three quarters, only one student answered “Disagree” or “Strongly Disagree” to all three statements. Interestingly, of the 108 students surveyed, only two remarked that they made no changes due to peer review.

Students also provided extensive comments with regards to aspects of peer review that were helpful to their learning and writing by answering the following free response questions:

- 1) What helped your learning?
- 2) How did these peer review sessions prepare you to write a better capstone report?
- 3) What in these sessions helped you become more confident about writing your capstone report?
- 4) How could these sessions better assist your learning?

In the first offering of the Winter workshop, the class participated in a discussion based on a reflective prompt: “Tell us something positive you saw in another student’s paper, so that we can all learn from it” (Figure 3).

Reflective Prompt: “Tell us something positive you saw in another student’s paper, so that we can all learn from it.”

- “My partner very clearly laid out the gap in technology in his Introduction, and justified the need for his own project strongly.”
- “My partner used a flowchart to summarize his method. It made the method clear and easy to understand.”
- “My partner used a table to organize dense information in the Design section. I could refer to it easily and read it quickly.”
- “My partner did a great job of summarizing within subsections, so that I had the context for all of the design decisions that he made.”

Figure 3. Sample in-class discussion responses to reflective prompt (Winter 2015).

Cover letters describing changes made in drafts due to peer review

Starting in Autumn 2015, when students submitted final drafts of their capstone reports to instructors at the end of Autumn and Winter quarters, we asked students to include a “cover letter” describing the impact of peer review. We emphasized that this could include changes made in response to feedback received from peers, and/or changes that students made because they were inspired by something they saw in another student’s draft. Examples of student statements from these cover letters are excerpted in Figure 4.

The emergent themes that we identified from the student cover letters are described in Table 2. The most common themes in student cover letters included:

- 1) Expanding or clarifying the background and significance of their work, especially noting the clinical significance or specific impact of their project;
- 2) Structural changes in formatting or organization of sections;
- 3) Improvements in clarity and ease of reading such as eliminating unnecessary or discipline-specific jargon, and defining acronyms at their first use.

Excerpts from Student Cover Letters

"One of the major things I learned in peer review was to be conscious of the reader."

"I think that having people who are not directly working in the same field as me really helped me understand better what needed clarification and what was general knowledge."

"Overall, I found the peer review session and comments to be helpful in revising my capstone draft because I was able to get feedback from an outside perspective, as well as see examples of alternative approaches that my classmates used."

"Overall, the review has been a helpful tool for us to form groups that we can turn to when we would like to receive some feedback on our [progress]. I really appreciate my group, who paid attention to the details of my project. I am looking forward to more group reviews!"

"During peer review, I saw different ways of structuring the methods section. I really like the idea of making subsections... a consideration I had not made prior to the peer editing."

"The peer review sessions were exceptional. First off, brainstorming a list of criteria for the intro and methods allowed introspection on my understanding of what my goals were in writing this report. The additional input from my group members further compounded this result."

"The handouts on a good intro and methods section [rubric] we discussed in class will continue to be a source I refer to as I aim to complete my writing and improve its quality."

Figure 4. Example excerpts from student cover letters.

Interestingly, instructors noted that several students demonstrated a disconnect in their perception of their capstone reports versus “real” publications. For example, one student commented that they received feedback on using more professional voice and presentation so that their report would read “like a real paper” (Table 2). Several students noted that they changed the style of their Methods section from a list of numbered steps (similar to a lab protocol) to paragraph form.

Overall, the cover letters indicated that peer review was very helpful and students enjoyed this experience. Students appreciated the opportunity to get a reader’s perspective on their drafts, and students noted that it was especially helpful to receive feedback from someone outside of their field. In addition, students enjoyed peer-to-peer learning, and several students noted that they were inspired by something they saw in another student’s draft. Finally, students appreciated the opportunity to create their own rubric by brainstorming a list of what constitutes “good” writing in a capstone report, and many students felt that generating the rubric helped them write a better draft.

Table 2. Emergent themes from cover letters submitted with capstone draft reports 2015-16.

Emergent Theme	Subthemes
Background and significance	Expand literature review Addition of information Provide medical context and significance (stats on disease prevalence) Clarify motivation (Articulate how project will solve stated problem) Delineate my project from prior/current art
Format	Margins Font style (italics for scientific name, bold section headings) Line spacing Citation tools, reference manager
Organization	Reorder sections Create subsections and subheadings Creation of subsections (e.g. “chunking” to improve reader’s experience) Flow and transitions
Clarity and ease of reading	Eliminate or define jargon Define acronyms at first use Word choice (using consistent scientific terminology, using same word over and over again) Reduce redundancy
Writing style	Verb tense (e.g. active not passive, past/present as appropriate) Professional voice and presentation (“like a real paper”) Concise
Visual Communication	Addition of figure or table (e.g. add diagram showing strategy of methods) Add detailed captions Increase clarity of figure Editing figure (e.g. show both control and treatment)
Additional content	Social and ethical issues Engineering standards Cost table Add abstract Add appendix Add detail for clarity
Methods	Justification of approach (e.g. specific protocol selected for experiments) Details of methods Style (paragraph form instead of bulleted list in protocol format) Add topic sentence for each sentence of methods, stating the overall goal and summary

Summary of Iterative Changes to Peer Review Approach

In response to student feedback (surveys and cover letters) and instructor observations, we made substantial changes in the implementation and messaging of our peer review workshop series over the past three offerings.

Class time required to discuss drafts in small groups.

After the initial offering, students responded that they wanted more than 10 minutes for small group discussion of each capstone report, and this request was supported by instructor observations of level of engagement during the peer review activity⁴. In subsequent sessions, students were given 20 minutes to discuss each draft, which seemed sufficient.

Review drafts prior to in-class discussion.

In the first offering, students read drafts in class immediately before discussing in small groups. Although this ensured that every reviewer actually read each draft before the small group discussion, the class time spent on reading was a major drawback.

Overall, students agreed that it would be more effective to read their classmates' drafts prior the in-class peer review sessions. Although we found that giving students one week to read and review drafts outside of class before the in-class discussion was beneficial to most students, this approach meant that the level of effort invested in reading/review prior to class varied among students. A future goal is to identify an approach that will standardize the quality of reviewer effort and feedback.

Optimal group size for peer review.

By trial and error, we learned that the optimal group size for peer review is 4 students. This allows groups to review 2 drafts for 20 minutes each in two 50-minute class periods (4 drafts total, >1 reviewer for each draft). Student feedback indicates that 20 minutes is sufficient time to review each draft. Groups of 4 ensure that each draft will be discussed by at least 2 reviewers, despite any absence of a single group member. (In the first offering, groups of 3 meant that any absence of a group member resulted in a student receiving feedback from only one reviewer.)

Grouping students by capstone track is beneficial.

After the first peer review session in Autumn 2014, students were adamant that they would prefer to be grouped according to research theme. We grouped students by research theme in the following quarter (Winter 2015), but we did not notice any student benefit. This strategy was potentially a hindrance to students working on capstone projects in a very specific or unique research area, and this approach did not seem to be a good investment of instructor time.

For the second and third offerings, we did not group students by research theme. Importantly, students noted that it was beneficial to receive feedback from students who were not familiar with their field and/or the specific experiments involved in their capstone project. Students appreciated the “new eyes” and “fresh perspective” on their work.

In the most recent offering, we grouped students by capstone track (research + design, or research only). This strategy seemed to benefit students, as the capstone report requirements are substantially different between the two tracks: the research + design track requires a long report

similar to a manuscript submitted for publication, whereas the research only track involves a shorter report. These students go on to complete a team design project, which includes both a written report and oral presentation. Thus, grouping students by capstone track allowed students to review drafts in the format they were already familiar with from their own writing, which made review more efficient and meaningful. In addition, reviewers were able to make observations of peer writing that they could implement in their own drafts.

Classroom environment affects quality of peer review experience.

After the first offering, students requested a physical space more conducive to small group discussions. In subsequent offerings, we requested classrooms with movable desks and chairs that could be arranged in small groups. This was beneficial for the second offering.

However, we were unable to secure a similar classroom for the third offering, and in student feedback we noticed that several students noted that they would have liked to have talking points during the group discussion. At first, this was confusing to us because we did project guiding questions on the screen during the in-class discussion. Then we remembered that several groups opted to conduct their discussions in the atrium of the building due to cramped classroom space, which meant that these students did not see the slide containing guiding questions that was shown in the main classroom (see list in Learning Activity, Autumn Sessions 2-3). In the future, we will provide the guiding questions on handouts.

Students enjoy creating the rubric, but they found the rubric overwhelming.

A major innovation of our approach to peer review is the level of student engagement required in setting standards for both effective writing and expectations. In class, students specified a code of conduct during peer review, identified characteristics of good feedback, and generated a rubric to use while reviewing drafts.

Overall, students enjoyed the opportunity to create a rubric. However, some students reported feeling overwhelmed or limited by the rubric, which prompted us to change the rubric structure each quarter in hopes of improving its accessibility and usefulness. In the first offering, we observed that many students found it difficult to translate what is “good” about specific sections of a report into a rubric.²³ This prompted us to provide more structure for rubric creation in the second offering. However, the students did not connect with the detailed rubric compiled by the instructors.

In the most recent offering, instead of paraphrasing student comments from worksheets completed by students, we asked each group to submit a digital copy of their list of “good” characteristics. The instructors then cut/pasted the students’ own words into a class document. Student feedback on the utility of this rubric indicates that students want it to be more concise and streamlined. One student commented that they wanted “more overarching guiding questions instead of a dense rubric.”

Discussion and Conclusion

Overall, students reported that peer review was a positive experience that helped them write better capstone report drafts. Our approach to peer review is unique in the level of student contribution required for setting standards for both effective writing and effective critique.

Students established writing standards by generating a rubric in response to a prompt asking students to identify “good” aspects of scientific writing they had encountered already. The student-generated rubric increased student buy-in for peer review, as well as providing scaffolding for critical thought about communication.

Based on overall positive student response, our peer review workshop is a promising answer to students’ interest in more feedback and guidance on writing in their senior year. Combined with positive feedback, students’ request for more time and means to engage with one another’s work (such as increase class time for discussion, read draft prior to class, request for classroom with movable chairs/tables to facilitate group discussion), suggests that the students value this activity and take their roles as peer reviewers seriously.

A key aspect of our approach is the degree of reflection required of students toward learning, retaining, and transferring their in-workshop learning. The addition of the cover letter requirement is one of the most exciting features, as we observed that students took this assignment seriously and put a lot of effort into reflecting on their peer review experience. Writing cover letters summarizing the changes they made in their drafts due to peer review served not only as a very useful assessment tool for instructors, but also encouraged students to engage in meaningful reflection on their writing approach, and how peer review informed their future decisions when revising their final drafts.

Students also were actively engaged in the reflective activities leading to the creation of the rubric and report that they enjoyed creating a rubric. Going forward, our challenge is to compile student comments into a more concise rubric that will be an effective guide.

The degree of scaffolding for student critique was crucial in our efforts to provide a meaningful experience for students. A common criticism of peer review is that student reviewers can be unhelpful or vague. Our approach includes a structure to help students stay focused and provide helpful critiques. For example, students discussed what constitutes “good” feedback.

By scaffolding student engagement in this way, we enrich their learning experience not only with information they can use toward capstone report performance but we also provide an authentic opportunity for students to analyze documents and construct standards when no clear rubric has been provided. This provides practice for the communication challenges that most engineers encounter in their professional careers.

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Appendix A. Student-generated rubric Autumn 2014.

Lists reproduced from class discussion:

What makes a good Introduction section?

1. Why should I care? Highlight importance.
2. Previous work is cited, along with its limitations.
3. Brief introduction to technical jargon and abbreviation.
4. The work should be contextualized within the (broader) field.
5. The Introduction should err on the side of having too much background information, rather than too little.
6. The introduction should provide a roadmap to the rest of the paper.

What makes a good Methods section?

1. Using a figure to clarify complex processes.
2. Sources and precise names of reagents, etc.
3. Qualitative and detailed
4. Chronological order (of steps)
5. Methods section should say what each step achieves
6. Methods section should follow/support roadmap laid out in Introduction section

(Appendix A. Student-generated rubric Autumn 2014, continued)

402/403 Rubric Version 1: What makes a good Introduction section?

Category	Great for the readers!	Still working to improve.
Importance/interest: Why should I care?	The importance of the work is highlighted for the reader.	(Left as a thought exercise. What does a paper look like on its way to meeting a reader's needs?)
Background literature	Previous research/papers (that contributed to the ideas/foundation of the paper) are cited/reviewed, along with their limitations.	
Field-specific terms, new terms, abbreviations.	There is a brief introduction to abbreviations/technical jargon used in the paper.	
Context	The research in the paper is contextualized within the field.	
Information inclusion	The introduction errs on the side of too much information for the reader —ensures that reader quickly builds enough background knowledge to follow paper.	
Overview	The introduction provides a “roadmap” to give the reader a preview of the general structure and findings of the paper.	

(Appendix A. Student-generated rubric Autumn 2014, continued)

402/403 Rubric Version 1: What makes a good Methods section?

Category	Great for the readers!	Still working to improve.
Aids to understanding	A figure is used to help clarify complex processes.	
Specificity	Names and sources of important supplies/reagents are clearly cited for readers.	
Style and inclusion	The Methods section is quantitative and detailed (in contrast to the Introductions section).	
Structure and Sequence	The information in the Methods section is sequenced chronologically , so that the steps the researchers took are displayed in order.	
Context	The Methods section shows what each step achieves (rather than simply recording what was done at each step).	
Supporting global structure	The Methods section should follow and support the roadmap set out by the Introduction.	

Appendix B. Student-generated rubric Autumn 2015.

Peer Review Rubric

Your instructors used the information you provided in the rubric worksheet in class Mon 11/23 to create the following rubric for you to use in the peer review sessions in class on Mon 11/30 and Mon 12/7.

This rubric is only a guide.

- Every capstone report may not need to address all items described in the rubric.
- Of course, your peer review discussion is not limited to this rubric. Please feel free to comment on aspects that are not covered by the rubric!

What makes good Introduction and Methods sections?

	Excellent	Satisfactory	Needs improvement
Define ambiguous and field-specific terminology	All terms are explained clearly at appropriate level for intended audience. Acronyms are spelled out at first use.	Most terms are explained clearly at appropriate level for intended audience.	Many terms are not explained clearly. Many instances of unexplained jargon or acronyms.
Include descriptive captions for figures, diagrams, tables, etc.	Descriptive caption provided for all figures, diagrams, tables, etc. Reader can understand meaning without reading corresponding text.	Captions provided, but some info is missing. Reader must refer to corresponding text to understand.	No caption provided in any figure, diagram, table, etc.
Use proper citation format.	Citations are placed properly in text. The corresponding reference for each piece of information is easy to identify.	Most or all citations are placed properly in text. The corresponding reference for each piece of information may not be clear.	No citations in text. Difficult to identify corresponding references.

(Appendix B. Student-generated rubric Autumn 2015, continued)

What makes a good Introduction section?

	Excellent	Satisfactory	Needs improvement
Concise and clear	No extraneous information, each paragraph has clear goal.	Most paragraphs have clear goal, some extraneous info and/or some missing info.	A lot of extraneous or missing info. No clear direction.
Relevant background info provided	Enough background info provided to allow paper to be read easily. Relevance is clearly stated within context of previous work in the field. Provides framework for experimental findings and conclusions.	Not enough background info. Relevance is unclear or not described completely. Previous work not described in enough detail to provide proper context or framework.	Missing background info, discussion of relevance, and/or description of previous work.
Identify specific problem and need	Clear statement of problem and need. Clear statement of hypothesis (if applicable).	Problem and/or need described, but missing some detail.	Problem and/or need not described.
Broad context provided, and significance of project described in specific detail	Justification/reasoning for project and significance are clearly described in context of field. Detailed description of prior art and how this project improves on previous work. Organizational flow of Intro is easy to follow as broad info is funneled into specific info.	Context is provided, but some details are missing. Organizational flow is somewhat easy to follow.	Description of context and/or significance is missing. Organizational flow is difficult to follow.

(Appendix B. Student-generated rubric Autumn 2015, continued)

What makes a good Methods section?

	Excellent	Satisfactory	Needs improvement
Logical flow of description of procedures	Procedures are grouped by theme, then are broken down further into subgroups by topic. Step-by-step description of each procedure includes appropriate level of detail.	Procedures are described, but are not organized by theme. Most procedures are described in sufficient detail.	Description of procedures is not organized. Most procedures are not described in sufficient detail.
Clarity of procedures performed	Description of procedures is easy to follow. An easy-to-understand diagram or flow chart is used to clarify complex procedures, design iteration, etc.	Description of procedures is usually easy to follow. A diagram or flow chart is used if necessary.	Description of procedures is difficult to follow. No attempt by author to clarify complex procedures, design iteration, etc.
Enough detail provided so others can repeat procedures	Detailed description of procedures, materials (including manufacturer info), instruments, etc. Units are clearly defined. Descriptions are universal, not specific to individual lab setting.	Sufficient level of detail in description of procedures, materials, instruments, etc. Description may be specific to individual lab setting and/or otherwise not helpful for someone working in a different lab.	Not enough detail in description of procedures, materials, instruments, etc. Description is not useful outside of author's lab.
Clear description of engineering design (if applicable)	Detailed explanation of iterative processes, criteria for success, specs, etc. Clear parameters and values.	Some detail missing in explanation of iterative processes, criteria for success, specs, etc.	No explanation of iterative processes, criteria for success, specs, etc.

Appendix C. Student-generated rubric Autumn 2016

What makes a good Introduction section?

Broad to narrow structure

- As you progress through the intro, you should narrow in scope
- Non-experts should be able to understand and follow the topics being discussed.
- Basic/broad outlines and explanations of what the project entails and how it is to be carried out.
- Start broadly (framing problem) and go into specific details (how our project offers a solution).
- Intro flows well from big picture → more specific → application of paper

Objectives and Goals

- Can the reader identify your project goal in the intro?
- Explain significance and purpose (why project is different/better from previous approaches)
- Clear definition of project goals
- States the main deliverables and/or expected outcomes of project.

Background and Prior Art

- Enough background context but not over-description
- Give enough understanding about background of biology
- Enough background information for the reader to understand material without prior knowledge
- Explain how each protocol is useful and helpful in completing project.
- Clear relationship between previous work and your work.
- Uses relevant References
- Mentions any ethical, social, economic, and legal considerations.

Writing Style and Structure

- Clear and concise, but with enough details
- Good writing style (explain acronyms, and use consistent wording and tense)
- Jargon and technical processes are well-defined
- Include diagrams and figures when helpful
- Easy to understand for general scientific audience
- Proper spelling/grammar/punctuation

Logical flow

- Focus on branching points; logical flow
- Sets up for proposed solution, no gap in logic between establishing the need/context and proposing the solution, should flow
- Form a narrative – the intro should have a logical flow of information where topics are presented in an order that facilitates clarity

(Appendix C. Student-generated rubric Autumn 2016, continued)

Need and Problem Statement

- Addresses needs and stakeholders, the need is articulated well
- State how your solution addresses a need
- Include definition of problem and solution
- Demonstrates clear understanding of problem

Significance

- Highlight the significance of the work. The author has sold their work and the audience understands the importance
- Clearly states how work is novel and significant
- Address and analyze previous works. Indicate how the project's proposal is better.
- Should explain broad significance
Ex: instead of saying "vaccine is important", give applications of vaccine

What makes a good Methods section?

Writing Style and Format

- Use a concise and clear writing style – only say what you have to and say it well.
- Be specific – include technical details.
- Organize into sections with titles.
- Use subsections to help organize and compartmentalize a long methods section.
- Cites primary literature when necessary
- No superfluous wording but still has narrative
- Define acronyms
- Reference any techniques as necessary

Content of Methods section

- Clearly demonstrates statistics and mathematical analysis
- Make sure method section does not include any results

Good use of visuals

- Use tables/graphics when applicable
- Good schematic diagrams to illustrate the experimental setups (e.g. fabrication)
- Clear illustrations of techniques if applicable.
- Tables and charts to describe the more specific materials used, instead of using a big chunk of words.
- Flow chart of procedure

(Appendix C. Student-generated rubric Autumn 2016, continued)

Methods should be reproducible

- Detailed enough that someone reading the methods section could recreate the experiments
- Use technical terminology *and specific model/make* for all equipment mentioned
- All techniques have a method or refer to another publication that illustrates the method
- Describes protocols step by step, so that they are easily replicable.
- Clear list of reagents and vendors
- List all the materials, reader should be able to obtain all those materials based on the info you give
- Describes materials needed to complete experiments (ex: dilution factors)
- Lists all resources and facilities.

Logical flow

- Frame methods section so they connect well to results
- If the reader can make a flow diagram of your process after reading your methods, you're doing good
- Methods are easy to follow and presented in a logical order (i.e. order of experiments discussed in paper)
- Help the reader understand what is involved in methods used
- Provide rationale/motivation for the steps taken in each procedure.
- Clarify which/what phase(s) each step is part of
- Provide additional supplemental information (such as cost analysis) so that reader is aware of feasibility
- Explain assumptions, safety precautions, controls
- Make sure to justify assumptions or decisions made.
- Articulate on the functions of instruments, in case readers are unfamiliar with equipment

Acknowledgements section (end of paper) - Give credit to processes and tasks performed by third parties

Appendix D. Student Peer Review Survey 2014-16.

Student Survey: Peer Review of Capstone Drafts

The purpose of this survey is to obtain information about your experience with peer review in class this quarter. Survey results will be used to evaluate the use of peer review in future course offerings, and results may be shared for educational purposes only.

- This survey is voluntary. Choosing not to complete the survey will not affect your grade in the course.
- Your responses are anonymous and will not be reviewed until after the course is finished.

Please rate the following:

	Strongly Agree	Agree	Disagree	Strongly Disagree
Discussing what makes a good Intro/Methods section helped me clarify my thoughts and/or approach to writing my draft	4	3	2	1
I obtained feedback that helped/will help me improve my draft	4	3	2	1
Providing feedback to others helped me to clarify my thoughts and/or approach to writing my draft	4	3	2	1

Please answer the following questions regarding the peer review sessions:

- 1) What helped your learning?
- 2) How did these peer review sessions prepare you to write a better capstone report?
- 3) What in these sessions helped you become more confident about writing your capstone report?
- 4) How could these sessions better assist your learning?