

Pedagogical Strategies to Promote the Development of Graduate Engineering Students as Disciplinary Writers*

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Ability to write for disciplinary publication is a hallmark of disciplinary expertise. This article reports on the pedagogical strategies used in a semester-long graduate course offered to facilitate engineering students' production of a manuscript ready, or near ready, for submission to a peer-reviewed engineering journal at semester's end. Strategies of structure oriented students to the foundational components of a journal manuscript. Strategies of evaluation oriented students to self- and peer-evaluation, in preparation for the broader peer-review process that occurs upon manuscript submission. Each strategy presented was identified as instrumental in developing students' disciplinary writing skills and knowledge. However, each strategy appeared to have a window of heightened effectiveness, depending upon the level of a student's previous writing experience. This article describes pedagogical strategies that support disciplinary writing development and considers the effect of initial differences in writing ability in terms of the use and timing of these strategies.

Keywords: academic writing; civil engineering; pedagogical writing strategies; graduate students

1. Introduction

Successfully facilitating the development of engineering graduate students' disciplinary writing is essential, given its foundational role in engineering research. Competency in written communication makes possible the effective dissemination of empirical research findings. Further, many argue that the act of creating a written account of one's research findings is itself part of the research process [1, 2]. However, engineering faculty, like most faculty across disciplinary affiliations, often receive little, if any, formal pedagogical training to teach disciplinary writing [3]. Instead, most learn how to write for their discipline from their own faculty supervisor during graduate training [e.g., 4, 5]. Unfortunately, however, supervision at the graduate level can be "woefully uneven" [6, p. 298]. As a result, novice engineering faculty—and even more seasoned faculty—may lack knowledge of pedagogical strategies to support their own graduate students' development as disciplinary writers. Furthermore, imparting such knowledge on an individual basis is a time-intensive endeavor, a serious consideration given that the pace of faculty work has noticeably quickened [7] while faculty time remains a limited resource [8]. To complicate matters further, many engineering stu-

dents enter their graduate programs with little authentic disciplinary writing experience.

In response to the above challenges, a semester-long graduate course, "*Writing for Publication*," was offered within the Department of Civil and Environmental Engineering at the University of South Carolina, USA, for the first time in 2012. The three co-authors of this article taught the course, assisted by additional faculty from the Department of Civil Engineering who periodically served as guest speakers. The primary course objective was for each student to prepare a manuscript ready, or near ready, for submission to a peer-reviewed engineering journal at semester's end. An earlier manuscript appearing in *The International Journal of Engineering Education* [9] fully describes course logistics, which are briefly recounted in the following section. The purpose of the earlier manuscript was to report on key student performance outcomes, such as student rate of progress toward readying a manuscript for peer review journal submission. The current manuscript advances the previous one by reporting on the pedagogical course strategies students identified (through free recall) as the most effective in facilitating their development as disciplinary writers. The current manuscript also considers the effect of initial differences in writing ability in terms of the use and timing of these strategies.

2. Teaching-learning methodology

2.1 Brief overview of course logistics

The semester-long course was offered on a Pass/Fail basis, and met weekly for three hours. Course content introduced students to the purposes of the four sections of a standard engineering research article (Introduction, Method, Results/Discussion, and Conclusions). Course activities iteratively honed writing skills through the creation of successively more advanced manuscript drafts to meet the goal of preparing a manuscript ready for submission by course end. During a typical class session, one or a combination of instructors delivered an interactive lecture in the first half of the session; the second half was conducted as a workshop format so students could practice incorporating lecture material and strategies into their own developing manuscript. Students selected their manuscript topic in consultation with their faculty supervisor, and course instructors strongly encouraged regular faculty supervisor-student meetings about writing progress. Course pedagogical strategies, more fully described below, were selected for two reasons. First, strategies were chosen to reinforce the purpose and content in each of the four standard engineering research article sections. Second, strategies were chosen to heighten students' awareness that text written for intended publication must identify and meaningfully contribute to an ongoing scholarly dialogue within the discipline.

2.2 Student participants

The course enrolled 22 students (1 master's degree, 21 doctoral) pursuing degrees across four areas of civil engineering (environmental engineering, structural engineering, transportation engineering, and water resources engineering). Students were drawn from a broad band of nationalities and displayed varying degrees of proficiency with the English language. At semester's start, each of the 22 enrolled students provided a self-description of prior writing activities. These self-descriptions allowed students to be categorized as either "novice" or "somewhat experienced" writers. Of the novice writers ($n = 10$), four had coauthored a conference paper (but not a published/submitted journal paper) and six had not yet contributed to either a published/submitted journal paper or a conference paper. Somewhat experienced writers ($n = 12$) had coauthored at least one published/submitted scholarly journal paper. For most of these students, co-authorship was with their faculty supervisor. While two students noted that they had written the majority of the paper, the remaining students reported writing from half to less than a quarter of the text, with some

noting their contribution was mainly in the area of experimental support.

2.3 Measurement of perceived effectiveness of pedagogical strategies

Because of the exploratory nature of the course, students participated in several assessments of pedagogical strategies used to facilitate disciplinary writing progress. The purpose of these assessments was multifold. First, assessments prior to course conclusion provided instructors with formative feedback so their guidance could be closely tailored to students' current needs. Second, dedicated disciplinary writing courses are relatively rare in the graduate engineering curriculum, and literature available to guide instructors in their design and implementation is scarce. Thus, assessments to determine which of several pedagogical strategies used in the course were perceived to be most effective in facilitating disciplinary writing can inform future course offerings at this and other institutions. Finally, assessments were used to determine any differences in perceived strategy effectiveness across the semester for students categorized upon course entry as either novice or somewhat experienced writers. The last two purposes underpin the thrust of the current article.

Students reported on perceived effectiveness of course pedagogical strategies by responding to a midterm questionnaire, participating in focus groups held during the last class session, and responding to open-ended questions included as part of a larger course evaluation to which they responded within two weeks of course conclusion. Additionally, students' faculty supervisors responded to open-ended questions about perceived course effectiveness four months after course conclusion, following late spring and summer months that for many faculty-student pairs served as a period of intensive writing. In their responses, many voluntarily described pedagogical strategies used by their student advisee(s) in the previous months.

2.4 Description of pedagogical strategies

Pedagogical strategies perceived to be most effective in facilitating the development of disciplinary writing are detailed in this section. Each defined strategy is accompanied by a rationale for and description of use. Strategies were categorized into two groups. The first group, 'Structure,' includes strategies that orient students to the foundational components of a journal manuscript. These strategies assist students to organize ideas and content. The second group, 'Evaluation,' includes strategies that orient students to self- and peer-evaluation, in preparation for the broader peer-review process that occurs upon

manuscript submission. Differences in perceived strategy effectiveness across the semester for students categorized upon course entry as either novice or somewhat experienced writers are addressed in Section 3.

2.4.1 Strategies of structure

The first half of the semester-long course introduced students to the purpose of each of the four sections of a standard engineering research article (Introduction, Methods, Results/Discussion, and Conclusions). This introduction was followed by more detail-oriented discussions of the anatomy of a typical article, how to locate and read primary literature, plagiarism, and proper paraphrasing of others' work. Workshop activities facilitated students' identification and close review of five articles relevant to their research topic; students 'dissected' articles in small groups to more closely examine article anatomy. These articles then served as building blocks for each student's nascent literature review. As well, the review of these articles prompted consideration of how their own research might align with and extend the extant literature base in their inquiry area.

Three pedagogical strategies were identified as being particularly helpful during this foundational section of the course, the Deconstruction Process, Concept Mapping, and Successively Advanced Outlines.

Deconstruction Process

Definition and Rationale for Use: The deconstruction process was presented to the class by a civil engineering faculty colleague [10] who had created it

to assist the writing development of his graduate students. The process involves selecting a highly cited journal article and 'deconstructing' it into its basic components. In doing so, the student uncovers the underlying structure of the article genre, including how its various components individually and collectively contribute to internal consistency and overall meaning. Use of the process can address many novice writers' fears that the form and function of disciplinary writing are complex and mysterious. In short, the process helps the student dissect an article into several more easily understandable and seemingly accessible pieces. Further, it makes explicit the often tacit rhetorical strategies or 'writing moves' that connect ideas and sections. When the structure of the article is revealed, the student can then use it as a scaffold to support his or her own writing efforts.

Description of Use: Following the deconstruction process presentation, each student was asked to deconstruct an article closely related to his or her research from a journal in which he or she was interested in publishing. To start, the student carefully examined each main article section, including the Abstract, which is often overlooked in terms of importance [11]. In the Introduction section, for example, engineering articles often have four to six paragraphs. To deconstruct this section, students reviewed each paragraph in terms of its overall goal or purpose. Questions such as, 'How does it position the reader to the overall manuscript?'; 'What information does it offer to the reader?' and 'How does it foreshadow upcoming text?' were relevant in this process. Figure 1 shows the overall structure elucidated by our faculty colleague. He provided con-

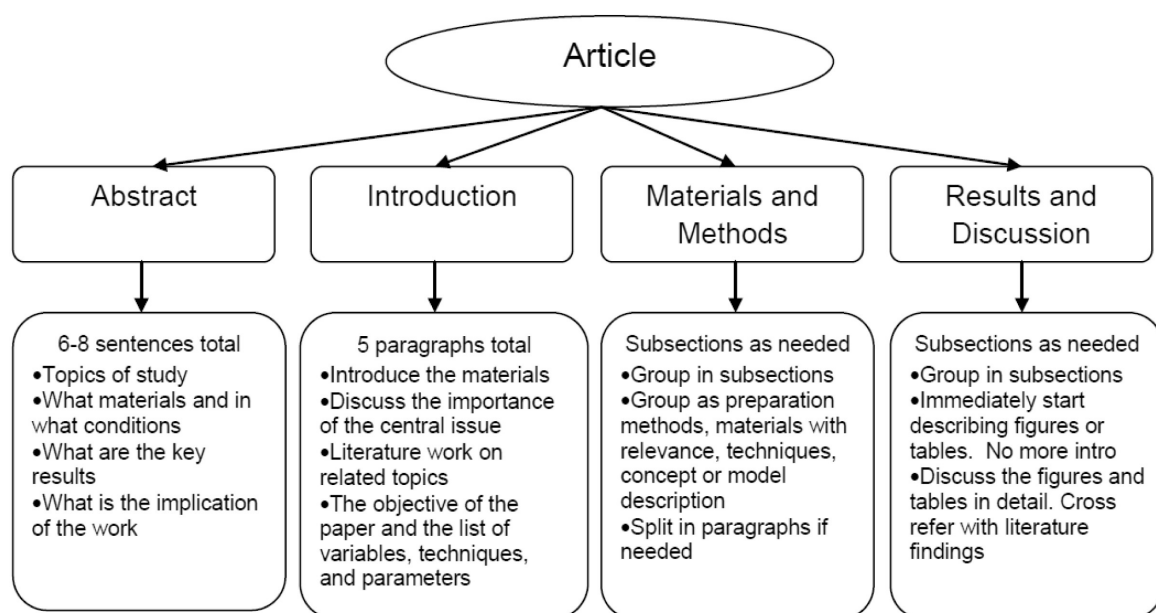


Fig. 1. Example of the Deconstruction Process (Journal-dependent) (after [10]).

crete examples of how to deconstruct an article by dissecting one of his own published papers.

Concept Mapping

Definition and Rationale for Use: Concept maps are “schematic representations of relationships between concepts” [12, p. 985]. Concept maps can assist students as they incorporate new knowledge into their existing mental maps or schemas. In the disciplinary writing course, students gathered a wealth of new knowledge as they reviewed relevant literature. Many, however, had trouble consolidating and integrating this knowledge in a way that allowed them to see both the ‘big picture’ of their area of inquiry and the gaps in the existing knowledge base. Constructing a concept map, starting with the five articles they each had located in their inquiry area, allowed students to do both. Additionally, constructing a concept map provided students with a sense of order and deeper insight into connections between what at first seemed like a group of disconnected articles.

Figure 2 is an example of a concept map used by one of the authors in her dissertation work. Concepts (in heavy solid text boxes) were desired instructional outcomes (goals). Pedagogical strategies in double lined border boxes were proposed means of achieving those goals. Data sources used to evaluate pedagogical strategies’ ability to produce instructional outcomes were in dotted borders. If prior research existed which supported the use of a pedagogical strategy for producing a particular instructional outcome, then those citations are labeled onto the line connecting the pedagogical

strategy with the instructional goal. Where pedagogical strategies’ ability to produce instructional goals appeared to lack prior research, proposed data sources used in the dissertation were inserted in the conceptual pathway.

Description of Use: The concept map shown in Fig. 2 was distributed to the students with a description of how it linked different article citations and collections of similar articles to interconnected concepts. Thus, it served as a visual organizer and identified conceptual gaps in the literature. As well, it helped the author to communicate to readers about the structure of the literature review it represented. Each student then created his or her own concept map, beginning with the five pieces of primary literature he or she had found earlier. Students were given a large blank sheet of paper (which can be taken from, for example, large flip chart pads or butcher paper rolls) and were encouraged to use pencils so they could easily make changes to their map both initially and over time. Students first summarized each of the five articles they had selected on a notecard. They were encouraged to identify the concepts or results from each article that were relevant to their own work by writing one concept or result per notecard. Students then arranged the notecards on the larger sheet of paper and determined the relationships between these concepts. For example, some students discerned hierarchical relationships that existed in which some concepts served as a broad category for a series of more limited concepts.

It was common for students to make several ‘false starts’ as they grappled with determining which

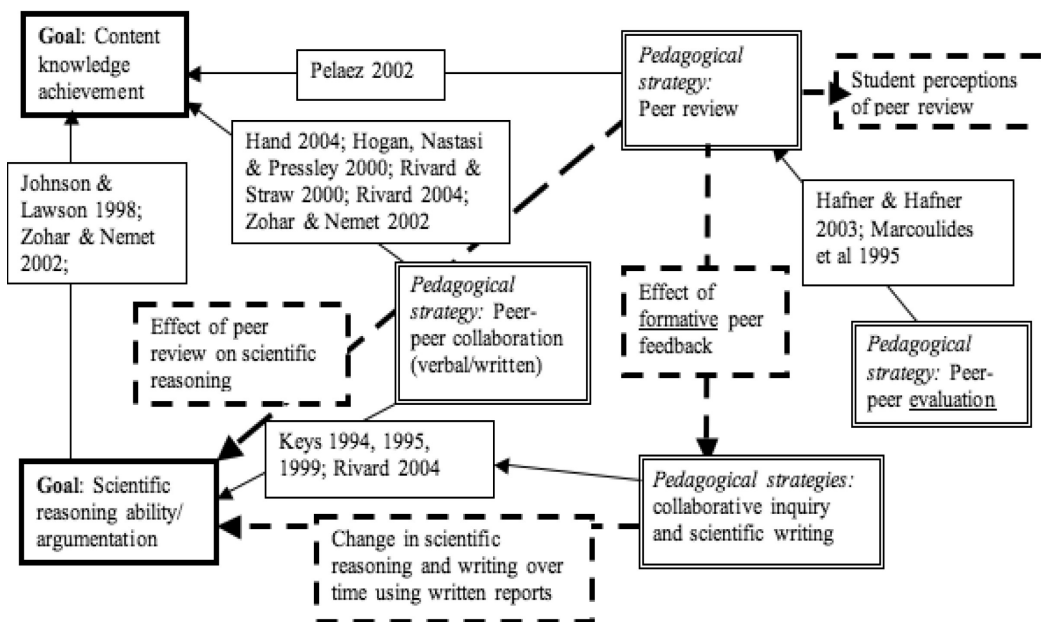


Fig. 2. Concept Map of a Literature Review.

concepts were relevant and the nature of the relationships between those concepts. As their understanding of the concepts and their interrelationships solidified, students continued to add citations to expand their map. They were encouraged to bring their maps to class on several occasions, showing peers and the instructors how they had modified their map over the span of several weeks. Many students discussed their concept maps with their faculty supervisors, describing how they visualized the interconnections among the literature they had read and where their developing manuscript might fit within the map. In fact, some students prominently displayed their maps by their desks or in other places within research labs to tangibly display their developing understanding about their line of inquiry.

Successively Advanced Outlines

Definition and Rationale for Use: Perhaps the hardest part of writing a manuscript is simply starting. Many students can feel overwhelmed as they begin to put words to paper, and envisioning the creation of an entire manuscript can be daunting. In response, students might be tempted to focus on a section seen as more straightforward, such as the Methods section, and leave other sections seen as more opaque, such as Conclusions, for last. However, this approach can undermine the sense of internal coherency required between manuscript sections, and within the manuscript as a whole. Additionally, this approach situates manuscript creation as a piecemeal affair. As a result, students can fail to see writing as a holistic, iterative process in which each section is drafted and redrafted, continually informed and shaped by changes and additions to other sections as the manuscript develops.

Description of Use: To address these concerns, students constructed successively advanced outlines of their manuscript. They began by constructing a *one-page outline*. As shown in Fig. 3, the outline,

which is constrained to a single page, prompts students to briefly describe their manuscript's literature base, research questions, methods and data sources, and anticipated results. Students are also asked to create a provisional manuscript title and identify journals to which to submit their manuscript. In identifying and discussing these components in concert, students were more likely to consider the cohesion of the text they produced. As with their use of concept maps, students used the one-page outline to facilitate discussions with their faculty supervisor about their developing manuscript. As they described their outline, students articulated their thoughts about their writing, in some cases revealing where and why they were encountering difficulties.

As the semester progressed, students moved from a one-page outline to a *beefy outline*. To create a beefy outline, students were instructed to draw upon the strategies discussed to date in class, including the anatomy of paper, the deconstruction process, and concept mapping. While the one-page outline might be considered an outline for an "elevator speech" (i.e., the amount of outline content is constrained to what can be clearly articulated in an elevator ride from top to bottom floor), a beefy outline might be considered an outline for conference presentation (i.e., the amount of content has increased to include what can be clearly articulated in a 10–15 minute research overview). Eventually, of course, the beefy outline content expands to become the full manuscript outline, the creation of which might at first seem intimidating to novice writers without intermediate steps.

2.4.2 Strategies of evaluation

The second half of the semester-long course was designed to reinforce the need to produce a manuscript that met three key criteria. First, the manuscript must include the content necessary to demonstrate that it was an account of a robust research effort. Students were counseled that miss-

Provisional Manuscript Title	
	<i>"Provide a brief description of each"</i>
Literature Base	
Research Questions	
Method/Data	
Anticipated Results	
Possible Journals	

Fig. 3. Image taken of One-Page Manuscript Outline.

ing relevant content invited readers’ skepticism about the quality and veracity of the research described within the manuscript. Second, the manuscript must be written such that it was easily understandable to disciplinary colleagues in and well beyond the classroom. As such, students were encouraged to create clear and concise text. Third, the manuscript must meaningfully contribute to a significant ongoing scholarly dialogue within the discipline. Students were advised that level of significance often made the difference between a manuscript being accepted or rejected for publication.

Two pedagogical strategies were identified as being particularly helpful to students as they evaluated their own and peers’ work in the context of the above criteria, the Manuscript Rubric and Figure Pair-Share.

Manuscript Rubric

Definition and Rationale for Use: A rubric is “a set of components of an assignment . . . accompanied by definitions of performance levels for each component” [13, p. 326]. Rubrics make explicit the expectations for performance. In mentoring students’ development as disciplinary writers, making explicit the criteria of ‘proficient’ disciplinary writing is essential [14], as disciplines vary widely in how written claims about knowledge are presented [15]. Further, within each discipline, sub disciplines communicate using specialized knowledge and language [15]. This range of ‘insider information’ can discourage a novice writer. However, a carefully con-

structed rubric that explicitly spells out the traits of ‘proficient’ disciplinary writing can guide a novice writer before and as they write.

Description of Use: Figure 4 displays a portion of the rubric provided to the students to reference as they individually drafted each section of their manuscript. This rubric was an adaptation of the Universal Lab Rubric (ULR) [16]. The authors of the current effort adapted the ULR to reflect perceptions of what constitutes effective scientific reasoning and writing in engineering literature, as well as criteria espoused by scientific journals. The revised rubric contained a list of evaluation criteria for the following research-related skills: setting the proposed research in context; framing practical research questions; aptly integrating primary literature; designing meaningful, reproducible experiments; addressing validity and reliability of data; selecting, presenting, and analyzing data; basing conclusions on data; and identifying alternative explanations and limitations of the proposed study. Definitions and writing prompts for each were included. For each criterion, descriptions of what engineering writing “looks like” when those criteria are met at the proficient, intermediate, or novice level were included.

The rubric can be used as a tool to both guide discussion about ‘proficient’ disciplinary writing and to evaluate the students’ writing that is in progress. In the disciplinary writing class, student pairs exchanged individually written work. Each student then applied the rubric to their partner’s

Criteria	0 Not addressed 0+	1 - Novice 1+	2 - Intermediate 2+	3 - Proficient 3+
Introduction: Context				
Demonstrates a clear understanding of the “big picture;” Why is this question important/ interesting in its field of engineering?	<ul style="list-style-type: none"> The importance of the question is not addressed. How the question relates within the broader context of the field is not addressed. 	<ul style="list-style-type: none"> The writer provides a generic or vague rationale for the importance of the question. The writer provides vague or generic references to the broader context of the field. 	<ul style="list-style-type: none"> The writer provides one explanation of why others would find the topic interesting. The writer provides some relevant context for the research question(s). 	<ul style="list-style-type: none"> a clear sense of why this knowledge may be of interest to a broad audience within the field writer provides explanation of gaps in understanding and how this research will help fill those gaps
Introduction: Accuracy and relevance				
Content knowledge is accurate, relevant and provides appropriate background for reader including defining critical terms. Background information:	<ul style="list-style-type: none"> is missing or contains major inaccuracies. is accurate, but irrelevant or too disjointed to make relevance clear primary literature references are absent or irrelevant. May contain website or secondary references <p>websites or review papers are not primary</p>	<ul style="list-style-type: none"> omits information or contains inaccurate information which detracts from the major point of the paper. is overly narrow or overly general (only partially relevant). Primary literature references if present inadequately explained. 	<ul style="list-style-type: none"> may contain minor omissions or inaccuracies that do not detract from the major point of the paper. has the appropriate level of specificity to provide relevant context. Primary literature references are relevant and adequately explained but few. 	<ul style="list-style-type: none"> is completely accurate has the appropriate level of specificity to provide concise and useful context to aid the reader’s understanding. Primary literature references are relevant, adequately explained, and indicate a reasonable literature search.

Fig. 4. Image taken of the “Context” and “Accuracy and Relevance” Criteria Portions of the Rubric for the Introduction Section of a Manuscript (adapted from [16]).

writing sample, assessing whether the sample was presented at a proficient, intermediate, or novice level (and noting when a criterion was missing). Students identified parts of the writing sample that were clear and fully developed, in keeping with the rubric, and parts where improvement was needed. They further offered ideas of how to implement needed improvement. In general, student reviewers have been noted to express concerns about offering meaningful feedback to peers in light of their own lack of writing experience or confidence [17]. However, providing students with a rubric that makes evaluative criteria explicit seemed to allay these concerns.

Figure Think-Pair-Share

Definition and Rationale for Use: Think-Pair-Share is a three-part collaborative classroom learning strategy [18]. “Think” refers to asking students to think about a problem; “Pair” involves pairing students to discuss their ideas for a solution; “Share” asks student pairs to share their solutions with the larger class. In the disciplinary writing class, a modified version of this learning strategy was used to showcase common problems associated with visuals such as figures and graphs. In engineering publications, figures, graphs, and other visuals are often included in written work to succinctly present a wealth of information. Unfortunately, when these visuals are not well or completely presented, they more often confuse than clarify. Therefore, given the ubiquity and importance of visuals in engineering publications, and the commonality of the problems associated with them (e.g., unclear titles, microscopic formatting, missing data, etc.), the disciplinary writing class content included a discussion accompanied by examples from “The Visual Display of Quantitative Information” [19] and a class activity about creating problem-free visuals to accompany written work.

Description of Use: Each student was asked to bring a copy of a figure or graph to class that he or she planned to use in his or her manuscript. Students were paired, with pair membership purposely mixed across research laboratories and engineering sub disciplines to heighten students’ awareness of the need for clear visuals. Engineering graduate students often collaborate in narrow subject areas, and a peer may tacitly and even unknowingly supplement his or her lab mate’s visuals with insider knowledge unavailable to others. Therefore, each student had the ‘fresh eyes’ of peers outside their laboratories and sub disciplines to review their partner’s work. Pair members reviewed each other’s visual, asking questions of clarification when necessary to highlight areas in which the visual was unclear. Pair members were also encouraged to

provide each other with positive feedback, noting when parts of the visual were well designed and easily understandable.

3. Main results/actual benefits of the approach followed for promoting professional skills

3.1 Categorization of student writing experience

At the midterm and conclusion of the disciplinary writing course, students identified (though free recall) the strategies they perceived to best facilitate their development as writers. Tabulation of these responses identified the five strategies detailed above. However, noticeable differences in response patterns emerged between novice and somewhat experienced writers. Some strategies appeared to better support writing development in students with little or no disciplinary writing experience, while others appeared to better support writing development in students with at least a modest level of writing experience. In this section, attention to timing is given to the effect of initial differences in writing ability in terms of the use and timing of various pedagogical strategies.

Of the 22 students enrolled in the course, 10 were categorized as novice writers. Of these, four had coauthored a conference paper (but not a published/submitted journal paper) and six had not yet contributed to either a published/submitted journal paper or a conference paper. The remaining students were categorized as somewhat experienced writers ($n = 12$). These students had coauthored at least one published/submitted scholarly journal paper. For most, co-authorship was with their faculty supervisor. While two students noted that they had written the majority of the paper, the remaining students reported writing from half to less than a quarter of the text, with some noting their contribution was mainly in the area of experimental support.

3.2 Writing productivity by student writing experience

Regardless of the extent of students’ contribution to a coauthored published/submitted journal paper, their participation as a co-author predicted, in general, both writing productivity achieved at course end and at six months following course end. As shown in Fig. 5 and Fig. 6, somewhat experienced writers constantly out produced novice writers across a range of production measures. Further, in comparing somewhat experienced writers to their novice counterparts, the average percent manuscript completion was 3% higher at course initiation, 21% higher at course completion, and 27% higher six months after course completion.

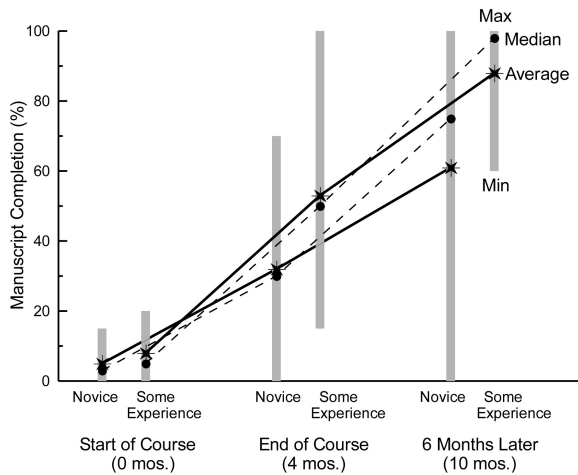


Fig. 5. Percentage of Manuscript Completion versus Student Writing Experience (for a complete description of assignment of completion percentage, see [9]).

Similarly, the median percent completion at the start of the course was 3% higher for somewhat experienced writers than novice, 20% higher at course completion and 23% higher six months after course completion. These differences are noted because they indicate that initial variation in writing experience, regardless of the extent of that experience, will likely predict the extent to which a dedicated disciplinary writing course will influence writing progress. These differences are also noted because initial differences in writing ability are important to consider in terms of the use and timing of various pedagogical strategies.

3.3 Response to writing strategies by student writing experience at course midterm

At course midterm (approximately seven weeks into the course), all strategies described above, with the exception of the rubric, had been implemented in the disciplinary writing course. An informal midterm course evaluation designed to inform instructors of students’ perception of course content mastery was

administered. Students were asked to identify course content that was ‘clear’ and ‘unclear’ to them. Many (but not all) students identified one or more of the writing strategies in terms of helping or hindering their understanding of disciplinary writing. Of note, many more ‘somewhat experienced’ than ‘novice’ writers provided comments directly related to writing strategies, suggesting they held more sharply defined conceptualizations of them. As part of a larger discussion of students’ progress to date, instructors analyzed responses in terms of student categorization as ‘novice’ or ‘somewhat experienced.’

3.3.1 Novice writers’ response to writing strategies at midterm

In terms of strategies of structure, the deconstruction process was well received by novice writers while the one-page outline failed to draw their notice. The concept map received mixed reception; some perceived it as useful, some did not, as reflected in comments such as:

[I understand] how to organize all the related literature . . . The [concept] map can bring me a clear overview of literature.

What has been a little confusing to me is how to set up the conceptual map, since it involves all the ideas around it, and the key concept that I might be missing is how to glue all these ideas together into a map.

In terms of strategies of evaluation, at the midterm, only figure think-pair-share had been introduced to students. No novice writer identified this as helpful, but a few found it unclear, with one stating, “[I don’t know] how to explain the figure and the table in the results very well.”

3.3.2 Somewhat experienced writers’ response to writing strategies at midterm

In terms of strategies of structure, several somewhat experienced writers clearly perceived that use of the

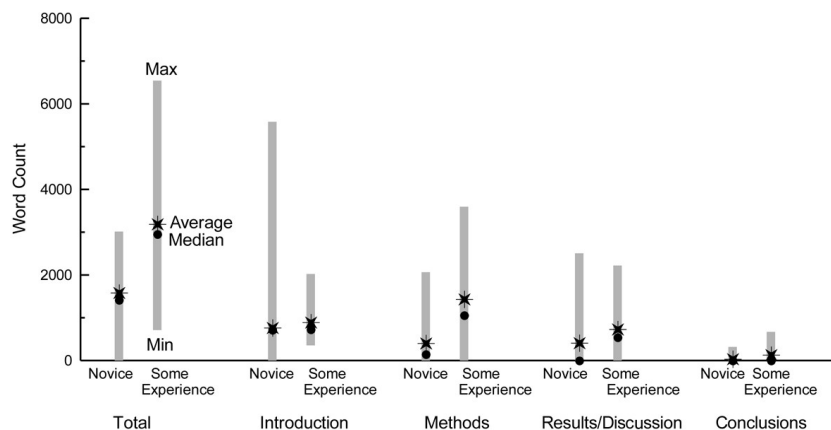


Fig. 6. Number of Words in each Manuscript Section versus Student Writing Experience.

deconstruction process was helpful; none perceived it to be unhelpful. Representative comments included:

I understood very well how to deconstruct a journal paper and absorbed that style to write another paper to be submitted to that particular journal.

Organizing a paper varies journal to journal. It [the deconstruction process] demonstrates the systematic way of writing a paper in particular journals.

I understand how to make the structure of the new paper based on others from the journal where I plan to submit it.

The strength gained from reviewing other articles published in the journal to which the work is aimed [is helpful].

The concept map received mixed reviews from somewhat experienced writers:

Conceptual maps: I think they might help in specific situations where you have a large amount of data or information, for example, literature reviews.

The concept map construction is unclear to me. I understand the purpose and outline of forming a concept map very well but how to make a detailed map is not that much clear to me.

I need to work on conceptual map. I feel like I can't go deep inside while writing the introduction part.

The one-page outline was well received by somewhat experienced writers:

Outline: Can be a good approach for pushing a paper out.

Format of one-page outline that includes literature review lists, conceptual frame, [research question], etc. [is helpful]

I find the one-page outline particularly useful. In fact, when I wrote mine, I had recently had a "surge" of ideas that seemed promising to me; I put them in the one-page outline, showed them to my advisor, and he was very pleased.

In terms of strategies of evaluation presented prior to the midterm evaluation, the figure think-pair-share activity was perceived as helpful to somewhat experienced writers:

The topic that I understand better is graphs. This topic is very useful in my research because I have too much data and I have to present it [sic] in the best form. I think my graph and plots are very easy to understand by other reader.

Figures and tables and their requirements . . . I have been struggling with these topics during writing a paper and that is why they seem clearer to me.

3.4 Use of writing strategies by student writing experience at course conclusion

At course conclusion, students completed an informal course evaluation on which they were asked, "Which aspects of the course (activities, hand-outs, presentations, etc.) were particularly helpful to you and why? As at the midterm, many (but not all)

students identified one or more of the writing strategies in terms of helping or hindering their understanding of disciplinary writing. Also as at the midterm, many more 'somewhat experienced' than 'novice' writers provided comments directly related to writing strategies, suggesting they held more sharply defined conceptualizations of them.

3.4.1 Novice writers' response to writing strategies at course conclusion

In terms of strategies of structure, a few novice writers identified the deconstruction process and the concept mapping activity as helpful. Both were introduced toward course beginning and periodically recalled throughout the course. By course conclusion, the one-page outline had grown into a full-fledged outline for most students, and this strategy was not recalled at course end. Novice writer comments related to the deconstruction process and concept mapping activity included:

It [the deconstruction processes presentation] was a concise summary of how to write a paper.

[The deconstruction process presentation] about how to write the abstract and introduction is helpful.

The concept map gave me an opportunity to see the subject from whole perspective. I was able see the connections between my topic and relative area and found some relative papers that can help me in writing. Also, it acts as a checklist for my introduction. I was able to see which important aspect I've missed in the introduction part.

The class about the literature map is very helpful. It organizes all the literature and I really like that.

In terms of strategies of evaluation, novice writers appeared to focus less on the strategy (i.e., rubric or figure think-pair-share) and much more on the public peer evaluation. Some valued it:

Activities like workshops (advice from friends) [were particularly helpful].

Group works and peer reviews were helpful because we shared experiences one another.

I think most helpful thing was talking to classmates about papers.

However, a few novice writers were not enthusiastic about sub-discipline sharing:

Discussion was worst for me. Students who didn't have knowledge about my field were not interested in my writing. Thus, when we spent time to share feedback, it was not helpful for me.

Activity (groups) is less useful because people from different academic fields did not work together very well.

3.4.2 Somewhat experienced writers' response to writing strategies at course conclusion

In terms of strategies of structure, very few some-

what experienced writers recalled them at course conclusion. The only comments received included:

The conceptual map course [was particularly helpful].
The scoring guide to scientific writing [rubric] and the one-page outline are very useful tools.

In terms of strategies of evaluation, somewhat experienced writers overwhelmingly responded positively to these strategies that included public peer review. Representative comments included:

But the most helpful part was the open discussion among students after writing and getting everyone's point of view...

Peer-review helps a lot. It instantly provides opportunities to know other views on the paper.

The group feedback is very helpful. We were from different civil engineering fields and we realized that we need to write for the reader.

Activities of the three-person group had provided competition among us to improve ourselves.

The activities gave us the opportunity of learning from others and apply what we have learned from the class.

Exchanging work with other students for revision [was particularly helpful].

4. Future issues

As noted earlier, few engineering faculty supervisors receive any formal pedagogical training to teach disciplinary writing, and most learn how to write for their discipline from their own faculty supervisor during graduate training. However, as articles in this special issue of *The International Journal of Engineering Education* make clear, success in the engineering profession, whether in or beyond the academy, increasingly requires mastery of a range of professional competencies, including efficient written communication for broad dissemination. This manuscript showcased the pedagogical strategies that effectively developed graduate engineering students into disciplinary writers. However, the manuscript also calls into consideration future issues around disciplinary writing pedagogy.

Within the increasingly crowded graduate engineering curriculum, where is pedagogy for disciplinary writing best placed? Currently, this pedagogy is most often found at the faculty supervisor-student level. However, increasing demands on engineering faculty to simultaneously play many roles in the contemporary academy (i.e., researcher, project administrator, funding securer, teacher) suggest limited time and attention is realistically available for writing pedagogy. If writing pedagogy is placed within a dedicated class, can the graduate curriculum and crowded student schedules realistically expand to accommodate class participation? If writing pedagogy is placed across the curriculum, will students systematically secure the content and

strategies needed to support continual writing development? If writing pedagogy is housed outside of engineering education, can students secure the content expertise needed to accompany production of meaningful manuscripts? These are only some of the issues surrounding the pedagogy of disciplinary writing that await consideration by stakeholders of graduate engineering education.

5. Conclusions

The development of disciplinary writing skills while in graduate training is critically important to ensure that engineering professionals beginning their careers can effectively disseminate the results of their work across a range of audiences. To support the development of disciplinary writing skills, this paper presented an overview of five pedagogical strategies perceived to significantly advance the development of disciplinary writing in graduate students in the Department of Civil and Environmental Engineering at the University of South Carolina, USA.

Each strategy presented was identified as instrumental in developing students' disciplinary writing skills and knowledge. However, each strategy appeared to have a window of heightened effectiveness, depending upon the level of a student's previous writing experience. This article described pedagogical strategies that support disciplinary writing development and considered the effect of initial differences in writing ability in terms of the use and timing of these strategies. Novice writers found strategies of structure to be most useful, whereas more experienced writers found strategies of evaluation (i.e. peer review) to be most beneficial.

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