AC 2012-3661: PREPARING STUDENTS FOR WRITING IN CIVIL ENGINEERING PRACTICE

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Preparing Students for Writing in Civil Engineering Practice

Abstract

This paper describes a project designed to investigate characteristics of effective writing in civil engineering practice and improve writing instruction for students. The project analyzes documents written by civil engineering practitioners and compares them to papers written by undergraduate students in civil engineering classes. A major finding of the project has been that practitioners and students exhibit a fundamentally different view of writing: practitioners see writing as integrated with engineering content and practice, whereas students view writing as separate from engineering. In this paper, we present three cases studies that illustrate the empirical analyses that have led to this finding, focusing on organization, sentence structure, and grammatical errors. We then offer five specific suggestions for approaching writing in civil engineering classes so that students will be better prepared for writing in the workplace, discussing how these ideas have been implemented at the university where the project is based.

Introduction

In discussions of how to prepare students for engineering practice, the importance of writing is often emphasized. The need for improved writing skills is a regular finding in surveys of employers and graduates.[1,2,3] Practicing engineers note the importance of communication skills, including writing, for advancing their careers.[4] Accreditation criteria since 2000 have also reflected the importance of writing.

Within civil engineering practice, writing takes on an even more important role than in many branches of engineering. There is a vast array of writing behind any civil engineering project – qualifications proposals, cost proposals, scoping notes, technical memos, design reports, site visit reports, reports for regulatory agencies, e-mails among the team, plan sheet notes and special provisions for the construction contract, to name just a few. Civil engineering shares certain writing needs with other fields; for example, firms do not stay in business if they do not write effective proposals that win contracts. However, the consequences of writing in civil engineering can be even more profound. One industry insurer found that communication was a factor in 27% of the claims filed against firms.[5] In the worst case, ambiguous or inaccurate writing can lead to death or injury. Even if no injuries occur, ambiguous or inaccurate writing can result in an unintentional increase in liability for a firm and have serious financial consequences.

Given the importance of writing in civil engineering practice and the attention given writing generally, it is surprising that little research has focused on the writing of civil engineering practitioners. Well known studies such as Tenopir and King's survey of engineers' communication practices[6] or Winsor's studies of writing development[7,8] have little to say about civil engineering. Papers that do focus on civil engineering writing rarely have a basis in engineering practice. Papers from the 2011 ASEE conference offer a typical range: in many cases writing instruction emphasizes academic writing, such as theses, dissertations, and

academic journal articles. In other cases, instruction focuses on assignments such as proposals because they are a typical workplace writing task, but research rarely explicitly addresses how writing tips reflect what practitioners actually write. Some instructors have substantial experience in industry, but others do not.

As Donnell, Aller, Alley, and Kedrowicz have argued, a much-needed step in improving instruction concerns determining the specific characteristics of successful engineering communication for different settings, whether in academia or industry.[9] They warn about the difficulties of interpreting what is said by managers in surveys. A more direct route to understanding the features of workplace writing is to study the writing itself. We therefore have undertaken a project to collect writing from numerous civil engineering firms and civil engineering courses, analyze differences in the organization and language used by the practitioners and students, and design materials targeted at teaching students writing skills that are particularly useful for the practice of civil engineering.

Analyses conducted for the project have revealed specific writing features that differ between the practitioners and students. These features reflect a fundamentally different view of writing held by practitioners and students. At all levels – whether small word choice concerns or global content and organization issues – practitioners see writing as integrated with engineering, while students see writing as separate from engineering. In this paper we summarize findings for three language features, offering them as brief case studies that demonstrate the contrast between practitioners and students. The methods and results are summarized here but are covered in more detail in other publications.[10, 11] We then discuss teaching strategies for changing student practices and beliefs that are unlikely to be effective in the workplace.

In the next section, we provide an overview of the project. We then present each of the case studies, describing the methods and findings for analyses of (1) organization, (2) sentence structure , and (3) grammatical errors. This is followed by a general discussion of all three findings, with particular reference to student interviews that help to explain the results. The final section discusses teaching applications, including those we have already instituted and additional ideas.

Overview of the Project

Started with funding from the National Science Foundation, the Civil Engineering Writing Project has three parts: the development of a "corpus" of student and practitioner writing in civil engineering; analysis of the corpus and interpretation of the findings concerning the differences between student and practitioner writing; and the development of teaching materials targeted especially at writing for civil engineering practice. The project is based at Portland State University (PSU), where close to 100% of the civil engineering B.S. students want to work as civil engineers. The ability to write in the workplace is thus crucial for these students' future success. In this section, we provide a brief overview of the project; additional information can be found on the project website: www.cewriting.ling.pdx.edu.

Table 1 displays a list of the types of writing that have been collected in the corpus, which currently totals approximately 400 undergraduate student papers and 360 practitioner documents.

The papers come from 19 different courses. Most are from Portland State University, but additional lab reports and senior capstone reports were collected from more highly ranked programs, for future analyses which will compare universities. The practitioner documents were contributed by 10 engineering consulting firms in the Willamette Valley, Oregon. Texts from both groups cover general civil, structural, geotechnical, and transportation engineering, and some environmental engineering related to civil engineering projects. Authors include both native speakers of English and second language speakers.

Table 1. Corpus of Student and Workplace Texts in Civil Engineering

Genres	Student	Practitioner
Reports	✔	✔
Cover letters with reports	✔	✔
Technical memoranda	✔	✔
Proposals	✔	✔
Project-related emails	✔	✔
Lab reports	✔	
Essays on an engineering topic	✔	
Site visit reports	✔	✔
Plan sheet notes		✔
Special provisions		✔

The engineering firms were asked to contribute documents that were typical of their work and that had not been involved in any litigation. We did not ask for only outstanding examples of work because we wanted to include documents written under the real constraints of consulting practice (time, money, demands of diverse clients, etc.), just as student papers were written under the real constraints of school. The writing of engineers with less than two years of workplace experience was not included in order to more clearly distinguish between the student and practitioner groups.

An innovative aspect of the project is to bring a variety of perspectives to the analysis of the papers: language specialists, engineering faculty, engineering students, and engineering practitioners. The project team includes applied linguistics (who study language in different communication contexts), a practitioner, and engineering faculty. In addition, interviews with other practitioners, faculty and students are used to understand the contexts of the writing, to get reactions to the findings, and to confirm interpretations. To date, 12 students, 10 practitioners, and 10 faculty have participated in extensive interviews, and many more in informal interviews about their writing experiences.

Three Case Studies of Student vs Practitioner Writing: Methods and Findings

Case Study 1: Organization of Tech Memos

This case study focuses on the rhetorical organization of texts. The analysis identifies the "rhetorical functions" that are typically expressed and the order in which the functions occur. "Rhetorical functions" are meanings such as "provide background context," "report results of analysis," or "make recommendations for design" – that is, the general communicative purpose of a chunk of text. In previous work in rhetoric and applied linguistics, these functions are typically called rhetorical "moves."[12] The term is used to signify an analogy with chess moves. Like a chess player, a writer makes a series of moves. Each move has its own micro-purpose, while at the same time, the sequence of moves is important for the final goal. Moves do not necessarily correspond to marked sections of papers. They are identified with a bottom-up approach, by reading the paper and identifying chunks of texts that have a unified purpose. For a group of texts that address a similar audience and purpose, a general pattern of rhetorical moves can usually be identified.

A fair comparison between student and practitioner rhetorical organization can be made only when the texts they are writing have a very similar audience and purpose. For this case study, we therefore present the findings for just one kind of text from one specialization: technical memoranda (tech memos) from geotechnical engineering. The student papers were written to fulfill an assignment that closely mirrored the context and purpose of the practitioner tech memos. They were given a specific client, and were asked to analyze certain soil data and then write a tech memo to the client describing the results of the analysis and making recommendations about a value to use for a design. Of course, the student paper is still a class exercise, but the specified context, audience, and purpose for the paper are so similar to practitioners' typical context that it is reasonable to expect similar functions and organization.

For this case study, our motivating research questions were as follows:

> What are the typical rhetorical moves in practitioner tech memos? To what extent do student tech memos express the same rhetorical functions and use them in the same sequence? What impacts are differences in the students' choices likely to have on issues in engineering practice?

The student tech memos came from one senior-level course (from two different years); the practitioner tech memos from three geotechnical firms. Each text was read by at least two readers trained in applied linguistics and rhetorical analysis. Practitioners and faculty served as expert informants about engineering content and meaning when it was not clear to the readers.

When we began the analysis, a number of students and faculty predicted that the rhetorical moves and organization of practitioner memos would vary greatly. However, the practitioner memos turned out to be quite consistent, using the moves presented in Table 2, even though the headings given to sections of their memos varied greatly. Move 1 states the work that the firm has completed; it was described by practitioners as functioning not just to state the topic but to re-establish the contractual agreement between the client and consultant. Move 2 provides

context about the project. In interviews, practitioners noted that the recipients of the memos are often already very familiar with the context of the project, but these statements also serve to document the plans for the project at that point in time and can be memory prompts if questions arise months or years later. Move 3 recounts the methods and procedures for gathering data. Practitioners commented that even if clients do not care about the methodological details, this move serves to show that the firm followed standards of practice. Move 4 then describes data and the results of the analysis. Move 5 states recommendations for construction or for designs by other engineers – the point that the entire memo has been leading up to. Move 6 then makes a statement about liability limitations. This language was often boilerplate from the firm's professional liability insurer, and for one firm was included as a paragraph after they memo itself was closed. Move 7 functions as a closing, typically expressing pleasure at assisting the client or offering to answer any questions.

Table 2. Rhetorical Moves in Practitioner Tech Memos (with typical opening sentence for the moves)

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1. **Re-establish contact/contract with the client**
   At your request, we have completed a geotechnical investigation and preliminary design for...
2. **Provide context of project**
   The [State] Department of Transportation plans to replace the existing I-34 eastbound and westbound bridges crossing the Muddy River at Mile Point 50.75 in Samson County…
3. **Recount methods/procedures for data collection and analysis**
   On April 29, 2009, we performed a site reconnaissance…
4. **Describe data and results of investigation**
   Boring BH-1 encountered ±3 inches of asphaltic concrete…
5. **Make recommendations for design** (for construction or for design work by other engineers)
   Recommendations: [Followed by list of recommendations]
6. **State limits of liability**
   Our work was done in accordance with generally accepted engineering practices. No other warranty, expressed or implied, is made.
7. **Close memo**
   It has been a pleasure assisting you…

The most typical sequence of rhetorical moves for the practitioner tech memos is made visual in Figure 1 as Type 1. The linear nature of the organization obvious: the memos typically progressed from Move 1 to Move 7 in a simple sequence. Type 2 in Figure 1 presents the only notable variant for the practitioner memos. Moves 3, 4, 5 - which recount methods, describe the data and results, and make recommendations - were reiterated for projects that had multiple parts that required different analyses and recommendations. Even with that reiteration, the organization is kept very linear. In interviews, practitioners emphasized the need to make the sequence of information logical and predictable for their clients. Readers need to be able to skim and find information in places where they expect it. Most practitioners were not surprised that

organization was similar across firms because the documents are used throughout the industry. Predictability was described as making everyone's reading and writing more efficient, and providing less potential for information to be missed or misinterpreted.

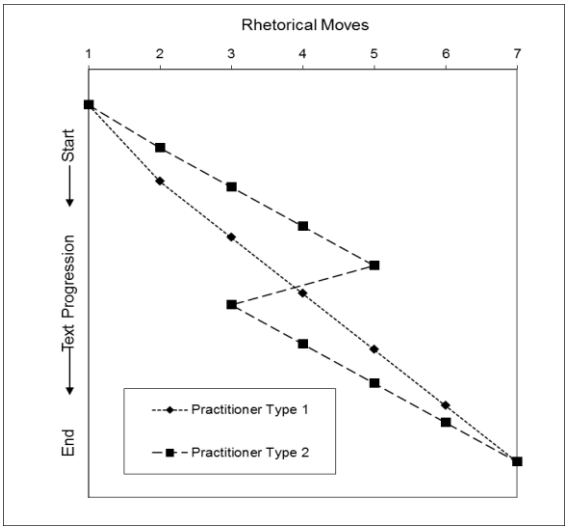

Figure 1. Sequencing of rhetorical moves in practitioner tech memos
Rhetorical move numbers correspond to Table 2: (1) Re-establish contact/contract with the client, (2) Provide context of project, (3) Recount methods/procedures for data collection and analysis, (4) Describe data and results of investigation, (5) Make recommendations for design, (6) State limits of liability, (7) Close memo

Student memos contained rhetorical moves whose functions were similar to those in the practitioner texts, but the number of moves and sequencing differed greatly. The student memos fell into three general types of organization (Figure 2), although there was a great deal more variation than for the practitioner memos. The most striking characteristic of the three types is their non-linear nature. Type 1 and 2 papers were characterized by a lack of rhetorical moves that showed the memo was written to a client. Type 1 memos looked essentially like the short answers to a homework problem with a memo heading at the top. Typically, they moved back and forth between results and information about methods multiple times, but with little written explanation. Type 2 papers were more like practitioner memos in linearity, but they essentially looked like lab reports with a memo heading. They covered context, methods, data and limitations by having the sections of lab reports: introduction, methods, results, and discussion. There was no acknowledgement of writing to a client. There also was a lack of explicit recommendation statements, perhaps because lab reports do not require recommendations. Finally, Type 3 papers were more like the practitioner tech memos in having more rhetorical moves, including an opening and closing that acknowledge writing to a client. The organization in between the opening and closing tended to be anything but linear, with some moves occurring repeatedly through the text.

Overall, reading the student tech memos is much like seeing the lines on Figure 2: a reader is likely to feel jerked back and forth from point to point. In sum, the organization was not linear

and thus would not meet concerns expressed by practitioners for giving clients a predictable sequence of information. There was little evidence of acknowledging a consultant-client relationship, and some neglected even to fulfill the ultimate request of the client, which was to make recommendations.

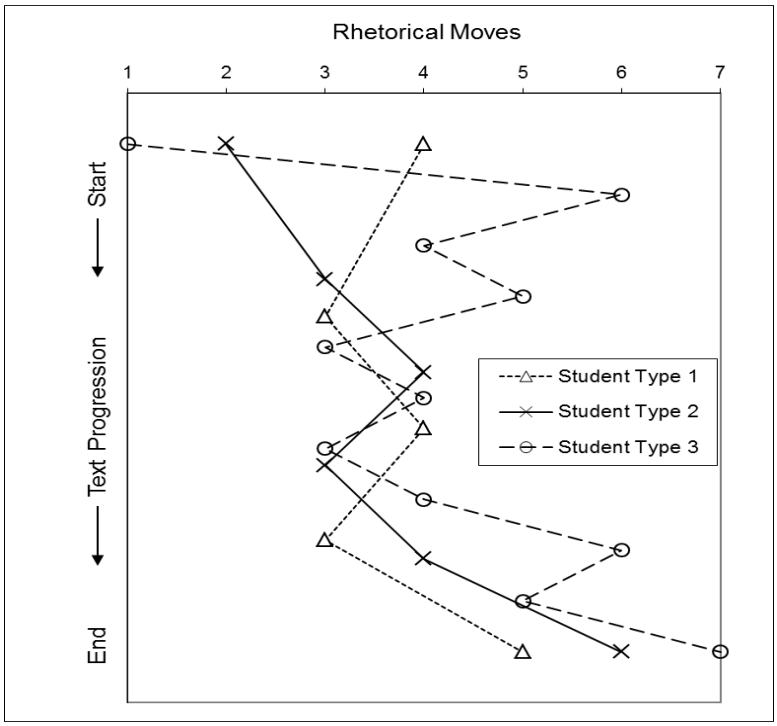

Figure 2. Sequencing of rhetorical moves in student tech memos
Rhetorical move numbers correspond to Table 2: (1) Re-establish contact/contract with the client, (2) Provide context of project, (3) Recount methods/procedures for data collection and analysis, (4) Describe data and results of investigation, (5) Make recommendations for design, (6) State limits of liability, (7) Close memo

Case Study 2: Complexity of Sentence Structure

This case study focuses on sentence-level concerns, specifically, the complexity of sentence structure used by practitioners and students. The research questions driving this analysis were as follows:

> Is there a statistically significant difference in the frequency of complex sentences used by practitioners and students? If so, to what extent do students' sentences demonstrate neglect for concerns that are important to the engineering practitioners?

For this analysis, sixty sentences were selected at random from different practitioner reports and tech memos, and sixty sentences were selected at random from different student reports, lab reports, and tech memos. Each sentence was categorized for the presence or absence of features of subordination or embedded structures. (These features include structures like relative clauses,

conditional clauses, and clauses within sentences such as "it could be recognized that the subject of the first test is most likely ductile." Further examples are below.) The difference in the frequency of complex and non-complex sentences for the practitioners vs students was tested statistically using a chi-squared test.

The students used statistically significantly more complex sentences (($\chi^2 = 3.93$, df = 1, $p < .05$). Only about 20% of the practitioner sentences contained complex structures, while over 35% of the student sentences did (Figure 3).

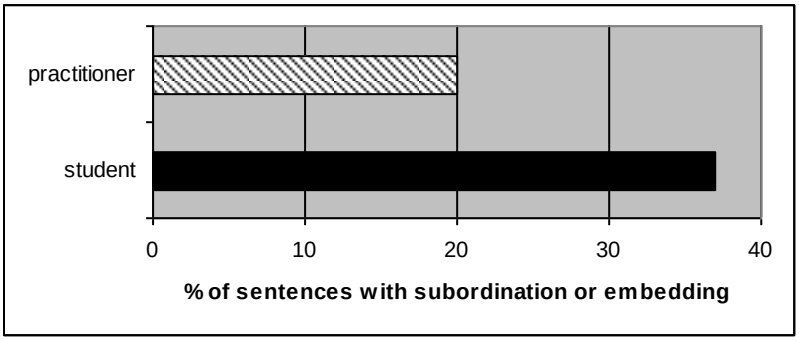

Figure 3. Sentences with subordinate clauses or embedded structures in reports and tech memos

Practitioner writing tends to have single ideas expressed in each sentence, for example:

> The rainfall depth was obtained from the City of [Name], County of [Name]. For the 25-year storm event, 24-hr rainfall depth is 4.0 inches for the site.

Sentences in the practitioner writing can contain many words and a great deal of specific information. However, the length is usually in long noun phrases and prepositional phrases that make information very precise. For example, the following sentence, might appear complicated:

> The lower portion of the embankment, below ±El. 475 to 480 and near Harmony Creek, is graded at approximately 1½(h):1(v).

The length, however, comes from the very specific prepositional phrases (*of the embankment, below...Creek, at...1(v)*), while the sentence structure remains simple. Commenting on the frequency of simple sentence structures, practitioners again noted the need to make information as easy as possible for clients to follow. They also noted that simpler sentences usually kept meaning as unambiguous as possible. The more complicated noun phrases and prepositional phrases result from the need for very precise and accurate information, especially about locations and quantities – an important aspect of engineering.

Of course, complicated information or relationships between ideas are sometimes most effectively expressed with complex sentence structures. The 1/5 of the sentences that were

complex typically were used for expressing reasons, purposes, and sources of information, as in these examples:

> We performed a site reconnaissance on June 3, 2010, to observe surface features.
>
> The study team conducted a review of existing bridge inspection records provided by the railroads and passed to the study team by [OrganizationName].

In contrast, many of the student complex sentences combine information unnecessarily, either making the information difficult to follow or raising questions in readers' minds about why the information is combined. For example, the following student sentence is not particularly long, but there is no good reason why the information about the "rest of the scarp" should be placed in a clause with *while*, making it subordinate to the earlier information in the sentence. Furthermore, the subordinator *while* is most common for information about time, but this is information about place:

> The highest elevation part of the scarp has the inclination of approximately 80 degrees while the rest of the scarp inclination varies between 40 and 60 degrees.

The above sentence is still comprehensible at least. Many other complex sentences by students have so many relative clauses and other embedded structures that the meaning becomes obscured, for example:

> The construction cost increases starting with prefabricated carbon steel storage tanks with construction costs including just the cost of the footing and installation, then to the bolt-together which would require footing construction as well as unskilled labor to put the plates together, and finally to the weld-together which would require footing construction and skilled labor to weld the metal plates together.

The complex clauses in students' writing are often in direct opposition to readers' needs for being able to understand information quickly. In other analyses[14] we have also shown that students' use of noun and prepositional phrases tends to make their content more vague, thereby also going against the need in engineering for accuracy and precision. In engineering practice, vagueness and ambiguity is also often a cause of unintentional liability.

Case Study 3: Grammatical Errors

For this case study, we analyzed the difference in frequency of grammar and punctuation errors in practitioner documents and student papers. We divided the student papers into those written for senior-level courses and those for junior-level courses because pilot work identified a much higher frequency of errors in the junior-level papers. The research question addressed in this analysis was as follows:

> Is there a statistically significant difference in the frequency of grammar and punctuation errors in papers written by practitioners, students at the senior level, and students at the junior level? How do any differences reflect concerns in engineering practice?

For the analysis, forty-five practitioner reports represented work from 8 firms. Thirty reports represented senior-level student work. Fifty-seven memos and lab reports represented junior-level student work. The student papers came from a total of 13 courses. All of the senior-level reports were team projects, with 4-5 students/team; the junior-level papers were primarily individual efforts. It is thus impossible to distinguish the effect of level (senior vs junior) and number of writers (group vs individual).

Errors were categorized into 5 major categories (see Table 3 for the explanation of each). The categories were derived inductively; that is, they were derived by making logical groupings of the errors that occurred in the texts, not decided a priori. The category of "article, prepositions, and other errors typical of ESL learners" contains those errors that are most commonly made by second language speakers but not by native speakers. Although native speakers make these errors as typos, we kept the category separate in order to get some sense of the extent to which errors were a reflection of general lack of proficiency in English as a second language.

Table 3. Grammar and Punctuation Error Categories

Verb Errors	Errors in tense or aspect, incorrect formation of infinitives or other verb structures (other than subject-verb agreement).
Sentence Structure	Any errors in the construction of sentences, including the structure of placement of relative clauses and "dangling modifiers."
Articles, prepositions and other errors typical of ESL learners	Articles, Prepositions, Plurals, Subject-Verb Agreement and Pronoun-Antecedent Agreement. Although these errors are sometimes made by native speakers of English, they are characteristic of English as a Second Language learners.
Spelling and Typos	Errors related to spelling or typing that do not fall into other categories
Punctuation	Comma errors, sentence final punctuation errors, and other punctuation errors

Only ungrammatical items were counted. Structures that were awkward but not technically incorrect in standard English were not counted. The errors in each category and the total errors were counted per text and normed to a count of 1,000 words because texts varied in length. Differences in total error counts for practitioner vs senior-level vs junior-level papers were tested quantitatively using a Kruskal-Wallis One-way Analysis of Variance. This test is a distribution-free equivalent of a one-way Analysis of Variance. The proportion of errors in each category was then compared across the groups and examples examined in the texts.

As Figure 4 shows, there were large differences in the number of errors across groups. Practitioner writing had few errors (on average about 4 per 1,000 words). Senior-level papers had, on average, about four times the number of errors of practitioners' writing, and junior-level papers close to 7 times. A double-spaced manuscript page has about 250 words; based on the averages, practitioners would have one error per page, seniors would have about 4 per page, and juniors would have about 7. The difference in errors was statistically significant across the groups overall ($p < .000$). The pairwise comparisons found a significant differences between the

practitioner writing and senior-level writing ($p < .000$) and between the practitioner writing and junior-level writing ($p < .000$), but not between the senior-level and junior-level papers.

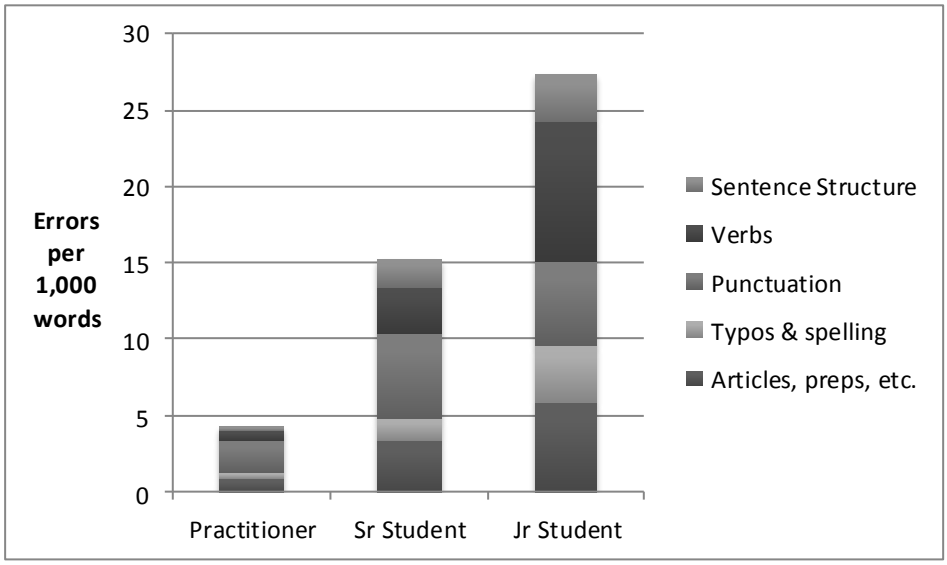

Figure 4. Frequency of errors in student and practitioner writing (per 1,000 words)

Most firms require that any document be reviewed at least once by a senior engineer before it is sent to a client (even if it is written by another senior engineer). Such reviews catch grammar errors as well as content errors. The results of our analysis suggest that students are not reviewing their papers thoroughly or do not know many basic grammar and punctuation rules. Even at the senior level, in papers that could be proof-read by numerous team members, student papers have far more errors than practitioner papers. Errors associated with second language learners were less common in the team project papers, but were still far more common than in practitioner papers. At the junior level the number of errors tends to be even greater. Overall, the error counts present a dismal picture of student writing.

Considering the types of errors between the groups raises even more cause concern. For practitioners, the highest proportion of errors concerns punctuation (about 50%, see Figure 4). The majority of these errors had to with commas, such as missing a comma at the beginning or end of a relative clause or after an initial connecting word, or adding an unneeded comma in a string of modifiers before a noun, for example (errors underlined):

> The bridge _which consists of about 700 feet of timber trestles and 700 feet of steel trusses and girder sections, was found to be predominately structurally sound...
>
> The building will house two, diesel-powered, 2MW engine-generators and will include electrical and storage rooms.

Although technically incorrect, such errors do not interfere with meaning. In fact, virtually none of the practitioner errors were important for meaning. The majority appeared to by typos missed in proofreading. In interviews, practitioners usually described themselves as not knowing grammar well, but striving for as error-free documents as possible to make sure meaning was accurate and to provide a professional presentation to their clients.

In contrast, student papers had more errors that obscured meaning. For example, students had more errors with verb tense, especially at the junior level. Their choice of tense often made meanings difficult to follow. Methods sections in lab reports sometimes varied apparently randomly between imperative (command) forms of verbs, present tense and past tense, as though parts of procedures had been done at different times (or were copied directly from the lab manual). Those sorts of errors were reduced in the senior-level group papers.

Students' sentence structures errors had the most serious effect on meaning. Sometimes they resulted in ridiculous meaning, as in this example where the students are literally saying that flood waters will stop and speak with a geologist before reaching the flood stage:

> After conversations with Jim Wheeler of the Geology Department, the 100yr flood event will likely have a flowrate of approximately 2700 ft^3/s…

Other sentence-structure errors were compounded by students' use of complex sentences. They resulted in ungrammatical sentences whose meaning is discernible but not clearly stated, as in this example from a lab report:

> But the brittleness of each coupon varied with coupon #3 having little necking and being the most brittle of the three coupons, coupon #13 had more necking than #3 but less than #7 and thus concluding it had the moderate ductility of the three coupons.

Here the student first combines sentences with a comma, and then ends with an ungrammatical "and thus concluding." Such sentences occur in senior-level reports also, often with nonsensical meanings, as in this sentence from a traffic analysis:

> Departures tended to have less pronounced localized peaks than arrivals, suggesting that departures are slightly less dependent on class time, as well as may account for the varying duration of class times (see Appendix Graphs A1 and A2).

Here the students' sentence reverses cause and effect, saying that the more varied departures account for the varying duration of class times, not that the differences in class duration account for more variety in departure times. In this sentence, as in the one above, a reader can guess the likely meaning, but that is not the meaning that is actually stated in the sentence.

In sum, this analysis found that there is a difference in the frequency of grammatical errors in practitioner and student papers, with the practitioners making far fewer errors. While senior-level student papers exhibited fewer errors on average, they were not statistically fewer than than in junior-level papers. Students' errors had a far greater impact by obscuring meaning and damaging the writers' credibility with a very high number of errors. Again, the student papers

exhibit characteristics counter to important factors for engineering practice – especially precise, unambiguous meaning and a professional presentation.

Discussion: Why Do Students Write the Way They Do?

The three case studies present a picture of practitioner writing as having predictable, linear organization, simple sentence structure but detailed noun and prepositional phrases, and few grammatical errors. These characteristics are related to presenting accurate, precise information as unambiguously and predictably as possible, and to giving the firm as professional an image as possible. In other words, these concerns are directly tied to engineering practice; they combine basic engineering concerns for accuracy and precision with practice concerns of meeting clients needs and limiting liability.

The three case studies present a very different picture of student writing. It has less predictable, less linear organization, complicated sentence structure with more embedding, and many grammatical errors. These characteristics lead to less accuracy and precision, and more ambiguity. Because of their greater ambiguity, they would likely lead to unintended liability for a firm. They also make information harder for readers to find and are likely to give an impression of unpolished work.

In interviews of students, several themes appeared that help to explain why student writing looks the way it does. One theme was the impression expressed by many students that writing was not truly an important skill for the civil engineering profession. Though they had been told this explicitly, they did not see it reflected in instruction or feedback on assignments. For example, when graduating seniors were asked what they had learned about writing in engineering, they consistently mentioned not using the personal pronouns *I*, *we*, and *you*, and formatting graphs and figures in particular ways. Never did a student connect writing to conveying precise, accurate engineering content. Some mentioned trying to proof papers for typos, but none connected correct grammar and punctuation with building credibility as a professional.

A second theme among the students was that complicated sentence structure made a better impression. Although a few students mentioned that their long sentences showed stream-of-consciousness thinking that never got revised, the following comments from interviews were more typical of students' explanations for complicated sentence structures:

> It looks better if it's longer. I think it's that simple.
> I think it's maybe just trying to sound like you know what you're talking about, or making it sound professional.
> I kind of felt like I had to sound professional and smart. I mean, you want to sound really knowledgeable about things, and it seems like the easiest way to do that is to be wordy.

Clearly, these students had not understood that for engineering practice, "sounding professional" would mean writing as simply and unambiguously as possible in order to convey accurate, precise meaning.

A third theme concerned the non-linear organization of papers. Several students noted that they often felt unsure about organization. Sometimes they knew the sections required in papers but couldn't figure out how to maintain a consistent focus within them. Sometimes they just did not know what a certain document should contain. Most of the students interviewed believed it was their responsibility to figure out organization for papers; as one said, "...we're being pushed, we should be able to look up – we should be able to design our own layout of a memo." Some noted that not knowing what to cover in a paper probably contributed to non-linear organization. As one student summed it up, "When you don't know what to do, you just throw up on the paper."

Given students' experiences, one might wonder how practitioners learned to write effectively. Three comments have been the most consistent. One has to do with taking reviews to heart. Many practitioners reported looking carefully at what supervisors or colleagues changed when they reviewed their drafts. One junior engineer described having to get over thinking that his boss was just on an ego trip, and then he realized the changes in his sentences had had an impact on the meaning. A second comment concerns the amount of time the practitioners spent improving their writing when they were junior engineers. Senior engineers commonly mentioned working extra hours on writing tasks when they started in practice, knowing that the hours could not be billed to a client but trusting that the effort would pay off later in being able to write more quickly and easily. Finally, all the practitioners referred to looking at previous documents produced by the firm, using them at first to learn typical organization and expressions, and later using them as templates for new documents. For most firms, much work is routine. Thus, it is rare that an entirely new document with new organization and new ways of describing content has to be created from scratch.

Teaching Applications

Based on the findings of our research, we believe it is important to integrate writing instruction into civil engineering education so that students appreciate it as part of their professional engineering skills, not a skill separate from them. At the same time, we recognize that civil engineering programs typically have several conditions that make writing instruction challenging: courses are often large, grading of written assignments (especially lab reports at lower levels) is often done by TAs who do not have experience in practice, and the curriculum is already overloaded, with no time for additional instruction. We have therefore sought ways to integrate writing into existing courses without taking substantial time away from the current content. We offer the following teaching suggestions, which we have begun to implement.

1) Establish the importance and amount of writing in civil engineering practice from the beginning of the program and reinforce it at each level. For example, in a first-year course offered for students considering the civil engineering major, we spend a class session reviewing the types of writing civil engineers produce, sharing practitioner comments about the importance of writing for advancing in their careers, and reviewing basic principles for making written explanations precise and accurate. We share examples from practitioner papers, and have students do a team activity revising poorly written sentences from previous students. The sentences practice the types of information students are likely to express in the site observation reports they must write during the term. At higher levels, we include short writing workshops focused on gradually more advanced writing concerns, as described in the next suggestion.

2) Explain writing and give feedback on writing as connected to meaning and the needs of clients, not just to formatting and style. As noted above, students in this study typically equated effective engineering writing with issues like not having grid lines on graphs and avoiding personal pronouns. To try to counter this kind of impression, we are now including short workshops (typically one hour) in junior- and senior-level courses that present a small number of writing issues in a way that shows their connection to meaning and clients' needs. For example, in one of the first courses that requires regular lab reports, we critique sentences students wrote in the past, such as the sentence "at really low temperatures, the energy required for fracture was..." The sentence is criticized not because it is "too informal" but because "really low temperatures" is imprecise and ambiguous; it can mean different things to different people. Such ambiguity is not tolerated in professional practice. Similarly, "the graph will allow you to calculate the modulus of elasticity" is not identified as ineffective just because it uses a personal pronoun ("you") but because the writer is implying the reader should calculate the modulus of elasticity from the graph – i.e., it is a problem of expressing meaning inaccurately. At higher levels, where students get assignments with real or invented clients, we focus on writing issues related to client needs. For example, in the capstone design course we focus more on relatively simple sentence structure with one main idea per sentence so that readers understand the meaning quickly. In a more advanced geotechnical course (which includes graduate students, many of whom are working in firms as they work on Master's degree), we address the choice of active and passive voice, and the use of active voice and personal pronouns for speaking directly to clients or establishing a firm's responsibility clearly.

3) Provide students with a target for organizing their papers. In practice, most documents will have a specified format and clients will typically either expect or demand that certain information is covered in certain sections. Rather than leaving students to try to figure out how to write a routine genre like a tech memo on their own, it makes sense to explain and exemplify what the target is. Especially when students face a new assignment type – such as the first times they are asked to write to a client – they likely need explicit instruction for how a civil engineer consultant writes to a client. Furthermore, faculty can reinforce the need to meet clients' expectations for content and its sequencing. As one faculty member explains for a proposal assignment that has very specific content and organization instructions: "In the professional world, all requirements of an RFP must be met for it to be considered. Obviously I will still accept your proposal if you don't meet all of the requirements; you will just lose points."

4) Show students examples of effective writing, explaining what makes it effective. Even when students are told writing principles to follow or organization to use, they often have difficulty knowing exactly how to manipulate the language in their own papers. Seeing effective examples and analyzing and revising problems as a class can be very helpful. In all the class workshops, we use examples from real practitioner and student texts, highlighting for students what makes the writing effective and leading them through revision activities. Even 20 minutes of concrete practice can be helpful. For organizing papers, we also recommend providing students with some formulaic language to help them begin each section, mirroring what practitioners usually write in documents. For example, Table 2 provides some formulaic expressions to use in a tech memo (e.g. "At your request, we have completed a ___ investigation of ___..." can be used to open the memo). Such expressions provide students with a scaffolding structure to help them

start expressing the content for each section of a paper without giving them so much language that they are just thoughtlessly copying. In addition, the formulaic expressions often serve as a check that all rhetorical functions have been fulfilled. For example, writers rarely forget to state recommendations explicitly when they use a formulaic expression to start a section "Our recommendations consist of the following: [followed by a bulleted list]." This formulaic language approach has been used very effectively in communication skills training for the Higher Education Engineering Alliance Project, an engineering education program for engineers in Vietnam (see http://heeap.org).

5) Reinforce the use of standard written English and effective proofreading as an important way to establish credibility as a professional. As noted above, the most important aspects of writing have to do with conveying meaning. However, it is also clear from our study that presenting oneself and one's firm in a professional way requires using standard English and proofreading carefully. As one practitioner commented, when he sees an applicant writing sample that has grammar and punctuation errors, it tells him the applicant is not detail-oriented enough to work as a professional engineer. Thus, preparing students for workplace practice means demonstrating to students that knowing standard English grammar is part of engineering practice. At Portland State, one way this message is being advanced is by including short grammar and punctuation practice in a required junior-level seminar introduction to the profession, with each practice culminating in a quiz. Students who do not pass the quizzes are required to take a technical writing course. In addition, use of non-standard English needs to be reflected in grades. We do not advocate a draconian policy where, for example, more than three non-standard uses results in a failing paper, but we do encourage marking down for errors that are frequent enough to damage a writer's credibility. Even second language speakers need to make the time to have a reliable proofing procedure, which may include getting help to find errors they cannot find on their own.

Many faculty and teaching assistants express doubt about giving feedback on sentence structure or grammar, claiming that they do not know English grammar well enough. In general, we have found this to be untrue. Engineering faculty do not need to know every subtle point of English grammar. We would argue that anyone who is grading papers should be proficient enough in English to identify sentences where the meaning is inaccurate or where the structure is so complicated that the meaning is impossible to understand; similarly, they should be able to identify papers that have numerous proofreading errors. Students need consistent feedback telling them that obviously inaccurate, ambiguous statements or numerous grammatical errors are not acceptable. As one student put it, knowing language use is part of the grade would "..get kind of a fire under our rear to have to do it right." This is an aspect we continue to work on at Portland State, with a department style guide as a first step that is currently underway.

It would be unrealistic to expect a civil engineering program to produce graduates who are perfectly prepared for writing in the workplace. Becoming proficient with workplace writing requires years of practice in the workplace context. Writing effectively requires skills and judgment, and these skills and judgment take just as long to develop as other engineering skills and judgment. We expect the development of other engineering skills and judgment to begin with foundations in general math and science courses, be developed more specifically in civil engineering courses, and then continue under the supervision of a Professional Engineer on the

job. Writing skill development needs to happen with the same progression. We would not expect students to take only math and science courses, and then make the jump to using those skills in engineering once they are in the workplace. In the same way, we should not expect students to take composition or general technical writing courses, and make the jump to using writing skills in the civil engineering workplace. Rather, civil engineering courses need to take an active role in developing writing expertise that reflects values within civil engineering practice, including precision, accuracy, consistency, and professionalism.

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