AC 2011-961: PRELIMINARY ANALYSIS OF STUDENT AND WORK-PLACE WRITING IN CIVIL ENGINEERING

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Preliminary Analysis of Student and Workplace Writing in Civil Engineering

In this paper we describe some preliminary results of a project that addresses a continuing problem in engineering education: the mismatch between the writing skills of engineering program graduates and the demands of writing in the workplace. This problem is commonly identified in surveys of employers, who express dissatisfaction with the writing skills of their new hires, and in survey of alumni from even strong engineering programs, who express dissatisfaction with the writing preparation they received[1,2]. In engineering education research, the problem has most often been examined with case studies of individuals[3], examinations of particular courses and internships[4], or surveys of the types of communication engineers undertake[5]. This project takes a new approach to investigating the problem and devising instructional materials. It focuses first on the empirical analysis of language features in a large collection of texts written by numerous students and practitioners. Instructional materials are then based on the specific language differences found between the student and practitioner texts. The project is innovative in including applied linguists (who study language variation in different communication contexts), engineering faculty, and engineers in local consulting firms. This combination, along with interviews of student writers, brings multiple perspectives to the interpretation of the language analyses. While the project focuses on civil engineering, the general approach can be applied to any field.

The belief behind the project is that teaching innovations are likely to be most effective when they are based on sound empirical evidence about the problem. Unfortunately, few engineers can describe writing problems in detail. It may be that students have not learned to express the same kinds of meanings that practitioners express. Alternatively, they may attempt to express the same kinds of meanings, but use different language choices or organize information differently. It is even possible that students are learning new writing styles that are effective but conflict with entrenched practices in firms. For each of these conditions, different educational interventions are likely to be most effective. Therefore, rather than assuming what the problem is, we choose to start with analysis of the writing.

For this paper we focus on two sentence-level grammatical concerns: sentence structure and the choice of active vs. passive voice. Numerous other aspects of writing are also covered in the project, including text-level concerns such as rhetorical organization. We have chosen to concentrate on sentence-level concerns here because they have received little discipline-specific attention in recent years. A great deal of work has advanced social theories of genres and described how learners come to understand the creation of texts in a discipline; for example, see work by Winsor[6] and the synthesis by Artemeva[7]. However, in such work, there is little concrete discussion of grammatical choices. Other scholars are more concerned with the actual writing that students produce, but they tend to discuss grammatical concerns as separate from disciplinary issues. For example, in encouraging more writing in engineering classes, Ceylan lists three areas to grade: ideas, content, and grammar[8]. Similarly, when Fisher, Usrey and Beasley discuss an effective online writing lab, they note the issues the online editors address – with "sentence-level issues of general clarity (concision, style, syntax)" separate from "advanced issues of rhetoric (audience, purpose) and analysis (claims, reasoning, evidence)"[9]. Although it can be helpful to think about different categories such as these when responding to writing, we

were concerned by a general sense in engineering education literature that grammar is somehow separate from the concerns of content, analysis, purpose, and audience.

Rather than assuming grammar can be separated from meaning, we decided instead to investigate whether even sentence-level grammatical choices reflect the content and values of engineering practice, and whether different grammatical choices by students are likely to be one factor that makes them appear unprepared for writing in the workplace. For the analyses reported here, we focused on the following questions:

1) In what ways, if any, do practitioners' sentence structures and use of active vs passive voice reflect concerns of engineering practice? In other words, do the practitioners just use standard English that could be used in any formal written communication, or are aspects of engineering practice integrated into the grammar of their texts?

2) To what extent and in what ways do students' sentence structures and use of active vs passive voice differ from the practitioners'? To what extent do differences demonstrate neglect for concerns that are important in engineering practice?

We answer these questions with an analysis of reports and technical memoranda (tech memos) written by civil engineering practitioners and undergraduate students. Because the analysis is part of a larger project, the next section provides an overview of the project and the texts collected for it. We then describe the findings of the grammatical analyses. We conclude by discussing the results in terms of student preparation for writing in the workplace. We share initial teaching applications in engineering classes, but the focus of this paper is on the analyses rather than the project's teaching materials.

Overview of the Project Design and Analytical Methods

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. The major does not require any writing courses beyond the general university requirements. However, classes for the major include many writing assignments: lab reports, essays about issues in the profession, various structure or site descriptions (e.g. visiting and describing a bridge for a bridge engineering class), design reports, proposals, tech memos, and numerous other writing tasks. In their capstone design course, students work on a design project for a real client with whom they meet. Some other courses invent client contexts for writing – for example, framing a homework analysis problem as a client's request for an investigation, with the results presented in a tech memo written to the client.

Ten engineering consulting firms in the Willamette Valley, Oregon, have contributed texts to the study. They represent the diverse range of consulting firms that hire PSU graduates, from small firms that specialize in work in the local area to branches of large national and international firms. They cover general civil, structural, geotechnical, and transportation engineering, and some environmental engineering (especially as it is incorporated into civil engineering projects).

Practitioners from five firms of different sizes and specializations have participated in interviews about their writing practices.

The research uses an approach from applied linguistics called "corpus linguistics," which incorporates computer-assisted analysis techniques with human interpretations of texts. The first step is to compile a "corpus" of texts and format them for computer analysis programs. For the full study, a corpus of texts is being compiled representing 7 main genres, some of which are written by both practitioners and students and others by only one of the groups (Table 1). Practitioner texts come from publicly funded projects and are thus public documents. The texts cover a wide range of content – bridges, buildings, highway expansions, foundations, retaining walls, traffic analysis, stormwater, hydraulics, and sight distance, among others. The student papers are from PSU classes, with an additional set of proposals and lab reports from Iowa State University and the University of Michigan; the additional papers will be used for a small comparison between PSU and these more prestigious engineering programs. The specializations are the same as in the practitioner texts (structural, geotechnical, transportation, and some environmental engineering as incorporated into civil engineering projects), and content is similar in covering buildings, bridges, roads, foundations, etc.

There are obviously practical constraints to the number of texts we can collect, including the types of assignments required in classes and writers' willingness to contribute papers. However, in each category, we strive to capture as much variation as possible: several different courses or firms, numerous specializations within civil engineering, a wide range of grades in student papers, and numerous different writers. Capturing the variability is crucial because the study seeks to analyze both the central tendencies and the diversity in texts; that is, we strive to find any typical patterns in organization and language choices for specific categories of texts, but also to describe the extent of variation within those categories. Many texts have multiple authors contributing to them. In total, 335 student writers and 100 practitioners are in the corpus.

The analyses presented in this paper use the report and tech memo genres. The reports come from 8 courses and 8 firms. The tech memos represent writing from two courses and 5 firms.

	Student	Practitioner
Main Genres		
Reports	86	74
Cover letters with reports	18	18
Technical memoranda	51	27
Proposals	20	20
Project-related e-mails	16	120
Lab reports	105	N/A
Essays on an engr topic	42	N/A
Site visit reports	44	20

Additional practitioner genres: Plan sheet notes, Special provisions

Table 1. Corpus of Student and Workplace Texts in Civil Engineering as of January 2011

The passive voice analysis was conducted with computer-assisted analysis techniques. Over 50 grammatical categories (e.g. nouns, verbs, relative clauses, passive voice, etc.) have been coded into the texts with a grammatical tagging software program[10]. With another computer program, passive voice structures were counted in each text by practitioners and each text by students. Frequencies were normalized per 1,000 words. The frequencies for the two groups (practitioners and students) were compared statistically with Analysis of Variance. Numerous passives were examined in context in the texts to analyze the functions that they served and the impact that they had. First person pronoun frequencies were counted but not analyzed statistically since they are quite uncommon overall. Their occurrences in conjunction with active voice were examined in the texts to interpret the role that the active voice + first person pronouns played and to identify their location in texts (for example, where in paragraphs they occurred and what kinds of meaning they expressed, such as describing methods or making recommendations).

Although several kinds of embedded and subordinate features (such as relative clauses and subordinate adverbial clauses) are grammatically tagged in the texts, the sentence structure analysis in this study was conducted by hand. We had already noticed some subordinate structures in student texts that would have been problematic for the computer tagging algorithms. Therefore, sixty sentences were selected at random from the practitioner reports and tech memos, and sixty from the student reports and tech memos. They were read and categorized for the presence or absence of subordinate or embedded structures (described further in the analysis section). The difference in sentence structure type was tested statistically using a chi-squared test. The complexity of noun phrases and prepositional phrases in the sentences was described to give a fuller perspective on sentence complexity, but it was not quantified for this study.

The analysis of grammatical features was conducted by an applied linguist. Interviews were conducted with practitioners, faculty, and students to verify interpretations and explore possible reasons for the findings. Interviewees were asked questions about specific language choices and about more general issues. For example, to discuss an active voice choice, a practitioner might be shown a passage he wrote and told, "I noticed you used 'we drilled' here instead of 'was drilled,' even though the rest of the sentences say 'was drilled.' Do you have any sense of why you made that choice?" A student might be asked "I've noticed that when students write methods sections, they use passive voice almost exclusively. Has passive voice ever come up in classes? Can you remember trying to use it – or not use it – in your own papers?" A faculty member might be asked, "Do you tell the students anything about using active or passive voice?" The interviews are meant to be another perspective for interpreting the analyses; they are not the primary focus of analysis themselves. (Numerous topics for other aspects of the study were covered in the interviews as well; they did not focus solely on sentence structure and passive voice.) At the time of this preliminary report, seven practitioners, seven faculty, and three students had been interviewed. Student contribution to the interpretations is thus limited, but we also have considered comments made by students during presentations and writing workshops based on this research.

Findings: Sentence Structure

We first became interested in sentence structure when the linguists in this project discovered that the practitioner texts were easier to understand than the student texts even though they contained more complicated technical information. The sentence structure analysis reveals one reason for this: the practitioners tend to use simpler sentence structure. The practitioner sentences more often contain just one clause, without subordinate clauses attached or other clauses embedded within. Only about 1/5 of the practitioner sentences had additional embedded or subordinate clauses within a sentence, but about 1/3 of the student sentences did (Figure 1). This difference was statistically significantly ($\chi^2 = 3.93$, df = 1, $p < .05$).
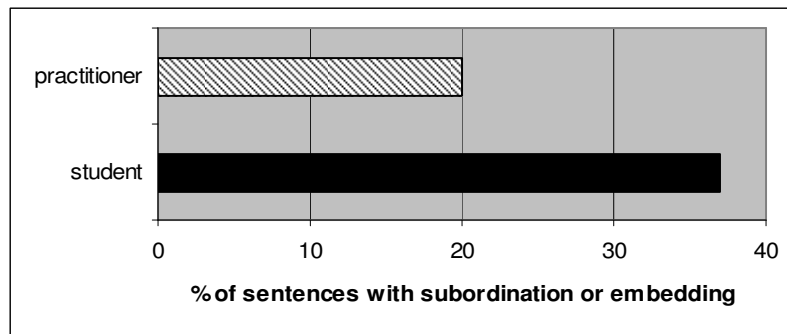

Figure 1. Sentences with subordinate clauses or embedded structures in reports and tech memos

Labeling practitioner sentences as "simple" is rather misleading, however. The sentences tend to have a different kind of complexity. Many contain complex noun phrases and prepositional phrases that make descriptions of locations, amounts, and objects very precise. The information is dense even though each sentence typically expresses only one main idea. The students, on the other hand, tend to write more complex sentences, with subordinate and embedded clauses that cover multiple ideas in single sentences. The information is less dense overall, and when the students use complex noun phrases, the nouns are more often abstract.

To understand the effect of these grammatical patterns, consider this comparison of practitioner and student texts that describe landslide and erosion problems:

Sample 1: Sentence Structure and Grammatical Complexity
A) Practitioner Writing
A section of the road embankment has eroded directly beneath and around the ±42-inch culvert near MP 0.75 on Harmony Drive. …
The surrounding embankment fill outside of the eroded zone is graded at approximately 1¼(h):1(v). The lower portion of the embankment, below ±El. 475 to 480 and near Harmony Creek, is graded at approximately 1½(h):1(v). The lower portion of the slope below the embankment is also covered with riprap.

B) Student Writing
The width of the existing landslide is approximately 70 to 100 feet and at the top of the landslide is the existing road with exposed foundation to the scarp. 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 practitioner text has four sentences that convey distinct information about the problem area – the problem location, the grading outside the problem zone, the grading of the lower portion of the embankment, and the riprap on the lower portion of the slope. At first glance, the sentences appear complicated, but the complex structures are noun phrases and prepositional phrases that make locations and sizes very precise (e.g. *directly beneath and around the ±42-inch culvert near MP 0.75 on Harmony Drive; the surrounding embankment fill outside of the eroded zone; the lower portion of the embankment, below ±El. 475 to 480 and near Harmony Creek*). The subjects of the sentences are concrete objects: *a section of the road embankment, the surrounding embankment fill, the lower portion of the slope*. Each sentence has one main verb (*has eroded, is graded, is graded, is covered*).

In discussing sentences such as these in interviews, practitioners make repeated reference to two concerns. The first – not surprisingly for any engineer – is the need for precise information. Locations, measurements, and descriptions have to be as accurate and precise as possible. It is inaccurate to write that "A section of the road embankment has eroded directly beneath the ±42-inch culvert" if the erosion is beneath and around. Similarly, the "lower portion of the embankment" has to be identified more clearly with reference to its elevation and the creek. These details that make information precise and accurate lead to the large noun and prepositional phrases. The second concern that practitioners mention is ease of reading for their clients. They strive for sentences that clients can read quickly with no questions about the meaning. Relatively simple sentence structure helps for this. The precise, accurate information and easy-to-understand sentences fulfill a need to communicate with as little ambiguity as possible. Not only are the clients happy, but practitioners note that this limits a firm's liability – a topic discussed further in the last section of this paper.

In contrast to the practitioner text, the student text in 1B covers multiple ideas in each sentence. The first sentence is a compound sentence that describes the width of the landslide and then attempts to express an idea about the location of the road and scarp. The idea is unclear due to a vague prepositional phrase (*with exposed foundation to the scarp*). The next sentence describes the two inclinations of different parts of the scarp, using a subordinate clause (*while…*). Several subjects are abstract characteristics (*width, inclination*). Some words add no meaning (e.g. the *existing* landslide). The result of the grammatical choices is that the student writing is less precise and more abstract. In fact, in sentences such as these, students' meaning also often becomes inaccurate. Here the students' literal description of the slide width is absurdly vague; they probably mean that *The landslide varies from approximately 70 to 100 feet wide.*

As Figure 1 showed, practitioners do use subordination and embedding in some sentences. When they do, however, the structure tends to remain straightforward. Practitioners' subject-verb-object ordering of each clause typically remains obvious and only one subordinate clause is used per sentence, for example:

<u>Sample 2: Practitioner Use of Subordination and Embedded Structures (in italics)</u>

A. In addition, this report contains cost estimating instructions and formulas, *which allow the user to estimate replacement and rehabilitation costs for additional bridges not included in this study*.

B. No jurisdictional ditches (or ditches of any kind) were present*, although storm drains capture roadway runoff along 17th Street below the bridge*.

The sentence in 2A starts with a simple sentence and then contains a relative clause that describes the object in the main sentence. The relative clause immediately follows the noun phrase that it describes (*cost estimating instructions and formulas*). Sentence 2B contains a main clause followed by a subordinate clause; each clause has a simple sentence structure. In contrast, when students use complex and embedded structures, they often compound their ineffectiveness beyond the problems illustrated in sample 1B. Many of their relative clauses do not immediately follow the nouns that they modify. The resulting sentences are usually interpretable, but they take work to comprehend and are often ungrammatical:

<u>Sample 3: Students' Ineffective Use of Relative Clauses (relative clauses in italics)</u>

A. A new road is constructed *which projects northward from the existing NE 32nd intersection adjacent to Bob's Market to a new intersection with NE Lewis*.

B. We designed an additional rainwater cistern because we knew that a pre-existing tank was already in place, *which included piping and distribution from the tank to various sinks within the town*.

In 3A the students are describing their redesign of an intersection. It is clear that the students mean "A new road, which projects northward…, is constructed." The relative clause is misplaced, perhaps because of the use of the passive voice, as discussed further below. In 3B the students are justifying a choice in their design of a water system. Their sentence structure problem does not concern just the placement of the relative clause. The relative clause does more than describe the tank; it describes distribution from the tank. The sentence is repetitive in describing the tank as *pre-existing* and *already in place*. Thus, the students seem to intend a meaning of "…because we knew that a pre-existing tank already included piping and distribution…" They do not need the double layers of a relative clause within a subordinate clause.

Other students increase the difficulty of their sentences by placing subordinate clauses inside other subordinate clauses. In the following example from a traffic analysis, a subordinate clause with *although* occurs as soon as a subordinate clause with *because* begins. Comprehension is made even more difficult by the use of two negatives (*unrealistic* and *does not affect*):

<u>Sample 4: Student Use of Multiple Layers of Subordination</u>
This particular modeling detail does not seem to greatly affect the output of the simulation *because [although it appears unrealistic], it does not affect the flow of traffic greatly and only seems to occur on occasion*.

Overall, then, what does this analysis of sentence structure tell us about practitioner and student writing? The grammatical choices of the practitioners do reflect certain concerns within engineering practice. Their use of dense noun and prepositional phrases and of relatively simple clause-level structure is a function of the need for precise, accurate information that is as unambiguous as possible so that it can be read quickly by clients and does not unintentionally increase the firm's liability. On the other hand, students' complexity in clause-level structure is diametrically opposed to clients' reading needs, and their more vague noun and prepositional phrases convey less precise, less accurate information. Some of the student sentences would be more effective if they applied principles that are often covered in basic technical writing classes, such as placing relative clauses immediately after the nouns they modify or avoiding double negatives. But to focus on the grammar the students chose as somehow separate from engineering would be to mislead the students. The problems in the students' sentences are tied to precision, accuracy, and a lack of ambiguity for clients – matters that are central to engineering practice.

Findings: Active and Passive Voice

The analysis of the use of passive voice and an associated use of first person pronouns (*we, our, I*) has caused a great deal of surprise among faculty and students involved in the project. Practitioner reports and tech memos use fewer passive voice verbs (i.e. more active voice) and more first person pronouns than student reports and tech memos. Although the differences appear relatively small as frequencies (Figure 2), the differences are statistically significant (for a combination of passive features, $F(1, 236) = 17.45$, $p < .0001$).
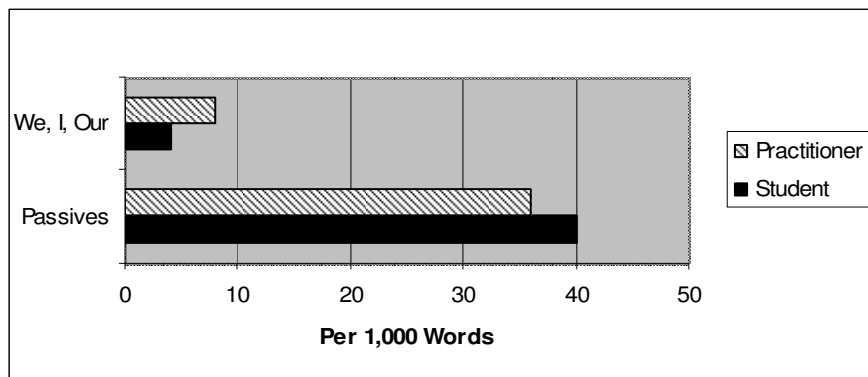

Figure 2. Frequency of passives and first person pronouns in reports and tech memos by students and practitioners

The difference in passive voice use is most notable in methods descriptions. When students describe methods, they almost always use passive voice. This is true whether a student describes a simple experiment in a basic Properties of Materials course, as in sample 5A, or tells assumptions for calculations in a more advanced Geotechnical Design course, as in 5B. (The lab report in 5A was not part of the quantitative analysis but is used to illustrate some of the entry-level writing students do.)

Sample 5: Student Methods Descriptions (passives in *italics*)

A. The slump test *was performed* in order to determine the workability of the concrete mixture. This *was done* by scooping the concrete into a mold the shape of an inverted cone in three layers. After filling each layer, the tamping rod *was used* to rod the layer 25 times.

B. The peak friction angle *was calculated* with the assumption of a uniform specific gravity of 2.65 and with the effective overburden strength equal to the effective stress of the soil. The soil *was* also *assumed* dry to the ground water table and completely saturated under the ground water table.

In entry-level classes with lab reports, students are regularly told to use passive voice for methods and to avoid first person pronouns. Students generally make no attempt to say who did the work or made assumptions. The lab reports are written in the context of the class, without a specific audience other than the TA or instructor who grades the labs. Generally, the student is assumed to be responsible for the work without overt mention of that fact. The practice of using passives apparently carries over into more advanced tech memos and design reports in higher-level classes. Sample 5B, for example, was written in a tech memo assignment where students were told to write to a specified client who had hired them as consultants. In most of those student memos, there are no grammatical differences from typical low-level student lab reports.

When practitioner consultants write for clients, their grammar choices exhibit some striking differences from students' choices. Although practitioners also often use passives, they use active voice as well. Practitioners are far more concerned with establishing their firm's responsibility for certain work or decisions. Many sequences of methods statements begin with active voice:

<u>Sample 6: Practitioner Use of Active and Passive (passives in italics, active voice underlined)</u>
On August 15 and 19, 2003, <u>we drilled</u> five exploratory borings with a portable drill rig using solid stem auger techniques. An additional boring *was drilled* September 18, 2003, northwest of the intersection using a trailer-mounted drill rig. These borings *were drilled* to provide data for retaining wall and signal pole foundation design. The boreholes *were drilled* to depths ranging from ±2 to 6 m.

Typical of many practitioner methods descriptions, the first sentence in sample 6 clearly establishes this firm as responsible for the borings by using *we* as the subject of the sentence. In fact, the engineering firm hired drillers to do the drilling, but they establish their firm as responsible. After the responsibility for the borings' existence has been established, the borings themselves are the topic of interest. Subsequent sentences use *borings* as subjects, adding information with passive voice. These choices of active and passive voice also make the sentences conform to the expected information structure of English: already-established (or known) information usually precedes new information. For example, the first sentence has known information as subject because *we* refers to the firm which is already known by the client, and continues with new information about the five borings. The subjects of the rest of the sentences are known information because of their relationship to the five borings established in the first sentence.

In interviews, when asked about active and passive voice choices, the practitioners expressed no conscious knowledge of information structure in English, but they did overtly describe the need to establish responsibility. They may have information from other sources, such as literature, previous reports, or data logs from other firms, and it is important to make explicit who was responsible for which data, analyses, and recommendations. The text acts as a record for the client and for the firm that did the work, and as a legal record if problems arise and liability becomes an issue.

Active voice sentences can be written with subjects other than first person pronouns. Even when *we* is used, it actually refers to the firm, not the specific writer of the text. Occasionally practitioners use the firm's name rather than *we*, but first person pronouns were a more common choice. Outside of methods descriptions, *we* + active voice also appeared at other points where the responsibility for actions or decisions was especially important, for example:

> Sample 7: Practitioner Writing with *We/I* + Active Voice (underlined):
> A. At your request, <u>we have reviewed</u> the Federal Emergency Management Agency (FEMA) documentation dated June 2, 2008, and the proposed changes to…
> B. During the site visit, <u>we observed</u> that a ±110-foot long section of road was cracked and had sagged ±6 to 12 inches…
> C. Shaft stabilization will be required. <u>We recommend</u> at least 20 feet of temporary surface casing.
> D. In conclusion, <u>I</u> hereby <u>certify</u> that the intersection sight distance at the proposed access for [address] conforms to the requirements for sight distance as set forth in the [CityName] Development Code.

Sentence 7A opens a tech memo, re-establishing the contractual agreement between the firm and client and explicitly stating the work the firm did. In 7B, the writer makes explicit the firm's direct observations (distinguishing them from information received from the client). Sentence 7C is very direct about the firm's recommendations. Sentence 7D provides a direct, legal certification where the agent (*I*) is important because he has legal authority to certify sight distance. In these cases, as in methods descriptions, the use of *we* or *I* makes the agent of the action explicit. The writers are not making a choice about the voice of the verb but about the subject of the sentence because the responsible agent needs to be unambiguous.

Outside of methods sections, and particularly in design reports, students' use of passive voice often contributes to ambiguity. For example, in the following student paper, it is not clear who noted the pedestrian activity or who recommended the improvement:

> Sample 8: Student Passives with Observations and Recommendations (passives in italics):
> Pedestrian activity *was noted* near the intersection of X Ave, Y Ave, and Z Ave. The width and unusual geometry of Z Ave made pedestrian crossings difficult. It *was recommended* that some form of pedestrian improvement was necessary to increase the safety of crossings.

Even in the larger context of the paper, it is impossible to tell who is responsible for the observation and recommendation. The use of passive voice and past tense for the recommendation suggests someone else made the recommendation earlier, but no one else is

identified in the paper. The sentence is consistent with students trying to avoid first person pronouns – something that students in interviews have repeatedly noted they learned to do.

Sample 8 also illustrates how students' use of passives sometimes corresponds to inaccurate content as well. The meaning of the sentence is reversed (pedestrians are not being improved to increase the safety of the crossing; the crossing is being improved to increase the safety of pedestrians). In the worst cases, students combine a complicated sentence structure with passive voice, as in sample 9:

> Sample 9: Student Sentence with Embedding and Passive Voice
> References found relating to the compaction of soils where the nature of the clay mineral changed after drying compared to using soils without initial drying was not clearly found.

Here the student's basic clause is an ungrammatical passive: "References was not clearly found." The student attempts to use a passive structure to modify the subject (*found* is related to the relative clause structure "which were found"), but it makes no sense (especially because the *references found* were apparently not found!). The student then has another clause structure modifying *reference* (*relating to…*) which has another clause modifying part of it (*where…*) and yet another clause (*compared to…*). Ultimately, the meaning becomes impenetrable.

Faculty do not want to read sentences like sample 9 any more than practitioners do. However, rules that faculty give students for writing seem to compound the kinds of problems exemplified in samples 8 and 9. Many faculty tell students to use passive voice and avoid first person pronouns. It is easy to understand why: faced with 80-90 lab reports every week, without sufficient time to thoroughly cover the basic content expected for the course let alone work on writing, and having seen numerous student papers with expressions such as *I think…* or *we feel the ideal location would be…*, giving students a rule to avoid first person pronouns and use passive voice can sound like a good idea. However, our initial interviews with students and comments during writing workshops suggest that students unfortunately apply such rules without connecting them to the engineering content. The students don't understand that the problem with *I think* and *we feel* isn't simply a matter of the pronoun use; the problem is that the content of engineering is not personal thoughts or feelings. In fact, in most cases the students do not literally mean *I think* or *we feel*; they mean that their analyses led them to a certain judgment, but they express that idea imprecisely. They do not get the message that lack of precision is a problem in writing just as it is in a calculation or that the solution to their problem is to express ideas precisely and accurately. Instead, they follow the writing rules. They use passive voice even when it makes meaning ambiguous or when knowing who made an observation and recommendation would be useful.

After hearing the results of our analysis of passive voice, one faculty member commented that the use of active voice and personal pronouns "just doesn't sound academic." Practitioners place no value on "sounding academic" and – as seen in the analysis above – use active voice and first person pronouns to make responsibility clear. Thus, the analysis of passive voice has also highlighted another problem that arises for preparing students to write in the workplace: though engineers in academia and engineers in practice share some values, such as precision and accuracy, other concerns of the practitioners – especially when they relate to liability – are not

central to academia. When students get a message to "sound academic," they can generalize it in ways that are inappropriate for workplace writing. For instance, some students have said that simple sentences just don't seem sophisticated enough. Thus, their more complex sentence structures may also be a reflection of the perceived need to "sound academic," which is in direct opposition to practitioners' need to be unambiguous.

Discussion: Writing as Engineering Judgment

We presented two questions to address in this paper, asking whether practitioners' sentence structure and use of active vs passive voice reflected concerns of engineering practice and whether differences in students' sentences reflected a neglect of those concerns. The answer is that the practitioners' grammatical features are consistent with the need for extremely precise information with as little ambiguity as possible, packaged to be read quickly – all of which lead to satisfied clients and limits on a firm's liability. Differences in the student writing – the more complex sentences, less dense noun and prepositional phrases, and greater frequency of passive voice – are ineffective for those specific concerns. Thus, even sentence-level grammatical choices do reflect values and concerns in engineering practice. Grammar choices are not simply a matter of using proper English or applying a rule. Rather, for the practitioners, grammar choices are integrated with judgment about how to convey information most effectively for engineering practice.

In calling for engineering classes to use more assignments that are similar to professional writing, Douglas et al note "The technical nature of engineering, and the financial and legal consequences of the work, means that graduating engineers probably require stronger communication skills than most graduating students"[11]. The technical nature of civil engineering is shared by the academic and practitioner contexts – yet the student writing in this study largely did not reflect an appreciation of the connection between the technical nature of engineering and writing choices. From student comments it appears that they consider writing to be separate from engineering – something that is covered by writing experts in a technical writing course or writing lab, not something that engineers know about. Some students have reported (although faculty might disagree) that they received almost no comments on their writing and that papers were graded purely for content, which they perceive as separate from the communicating of that content. Knowing they could get decent grades without making sure their writing was as precise as possible, they did not put time into revising it. Consistent with the students' perception, several faculty members have commented that they do not feel qualified to comment on students' writing. They do comment on content, so again the perspective in academia seems to be that the writing and engineering are separate phenomena.

However, beyond principles such as "be precise," which are too general to be of much help, formulating effective writing in civil engineering requires civil engineering judgment. Even the linguists working on this study – with years of experience studying writing in science and engineering - frequently have to ask the engineers whether certain language is accurate or precise enough. Other general principles that are typically given in writing classes, such as to vary sentence structure, are likely to lead to less effective papers if the principle isn't coupled with primary consideration of how to convey the information precisely and unambiguously in the civil engineering context. The link between writing and engineering content is far closer for

practitioners. One practitioner explained it, "Yeah, your calculations and analysis have to be right, but if you don't communicate them clearly, it doesn't matter that they were right – your clients are still going to be confused or do the wrong thing." Overall, then, it appears to us that one way engineering education is failing students in preparing them for workplace writing is in giving them the impression that the writing and engineering content are not inextricable linked.

The tie between their writing and the financial and legal consequences of engineering work seems to be even less familiar to students. Often, when the issue of liability is raised, faculty, students, and people outside of engineering express an expectation that liability concerns have a negative effect on writing; they assume it causes writers to use "weasel words," as many people call them. In contrast, in this study we are finding that concerns about liability lead practitioners to write as unambiguously as possible, including using first person pronouns and active voice. As one practitioner explained it, if a problem arises and a firm is taken to court in a liability suit (which happens fairly regularly in the world of civil engineering and construction), the best defense is to be able to show that the firm followed standards of practice and wrote information and recommendations that left no room for misinterpretation. If information or recommendations the firm wrote are deemed unclear or ambiguous, the firm will almost certainly be held liable. As he summed it up, "Ambiguity leads to liability." Given that virtually every problematic sample above made content ambiguous, it is easy to see how practitioners would look at new graduates' writing and declare the new graduates unprepared for writing in the workplace.

General technical writing principles are unlikely to be any more helpful to students for liability issues than they are for judging precise, accurate language. For example, one technical writing textbook gives students the appropriate advice, "If you want the focus to be on the receiver of the action rather than on the agent, then use passive voice. If, on the other hand, you want to emphasize the agent, use active voice"[12]. But how are students to know when, in a civil engineering report or tech memo, they should want to emphasize the agent?

We have pointed out some ways that uncoupling grammar and writing from engineering practice contributes to students' lack of preparation for writing in the workplace. To conclude this paper, we want to explain initial work related to our research to begin addressing the problem. We have begun with small changes that are easy to implement given the reality of the situation, which includes the facts that classes are large; faculty are under pressure to graduate many students; many faculty have not worked as practitioners in a firm and are not fully aware of financial and liability concerns in a company; and faculty have many demands on their time, including research, grants, and publications that will be given more emphasis for tenure and promotion than teaching student writing will. All of these are constraints on time, energy and money for developing students' writing skills. In addition, the B.S. curriculum is already extremely tight and, with pressure to graduate students in four years and tuition rising each year, adding courses is not a viable option. Nevertheless, we have found small ways to start a process of preparing students more effectively for writing in the workplace.

An overall goal is to change the perception of writing as separate from civil engineering. Here we share the items most clearly related to the grammar choices reviewed in this paper (others

relate to rhetorical choices, grammatical accuracy and other aspects of the study). We have materials on three levels:

- The exploratory, pre-major level: In a new exploratory course for students who think they might want to major in civil engineering, a class session is devoted to a review of the amounts and types of writing civil engineers typically do, with numerous examples of the texts. Students who believe they can be civil engineers without doing any writing have their misconceptions addressed before they choose the major. A very basic principle of making writing as precise as possible for technical content is introduced, with the class revising examples of ineffective writing – e.g. using precise measurements rather than descriptors such as "hot" or "a lot of," or revising a connector like "at the same time" when the author is describing space, not time. The level of technical information is quite elementary, but we seek to introduce the idea of precision in writing as part of civil engineering.
- Entry-level: At this level, students largely work on lab reports. In an entry level lab course, we have developed writing materials to emphasize the use of simple sentences and language choices, again emphasizing making information precise and accurate. Revision exercises using examples from previous student papers are included. In the coming months, this information and the exercises are planned as part of a website; this year during the first week the class included a presentation about writing the lab reports and discussion of revisions of ineffective examples.
- Senior level: In the design capstone course and electives (many of which also include graduate students) we conduct writing presentations and workshops that addressed issues related more to professional practice. Among other issues, the choice between active and passive voice is central. We introduce the concern for establishing responsibility and the underlying concern for liability, and the class analyzes practitioners' choices for active and passive voice in light of these concerns. We highlight the difference in this concern and the academic writing the students have been doing previously, and have students revise sentences that likely would be considered ineffective in a firm.

Admittedly, there is a long way to go in preparing students more effectively for workplace writing. We have not yet studied the impact of initial presentations and workshops, and we have the most difficult issues – such as writing feedback and the relationship to grades – yet to address. However, anecdotally, we have received comments from students that their understanding of writing in civil engineering has changed. Part of our goal for a new perception of writing is to have students (and faculty and practitioners) view it as judgment, just as engineering is judgment. Everyone involved in engineering education admits that judgment develops over time, with experience. Civil engineering graduates become engineers in training and learn more on the job. Employers cannot expect their writing judgment to be fully developed any more than their engineering judgment is fully developed, but they can expect the development process to have begun. Thus, we seek to make writing a greater part of the judgment students are developing in school, rather than having them learn to consider writing as separate from engineering or learn to follow rules that may not transfer well from academia to practice.

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