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Improving Student Writing with Research-based Instruction: Results from the Civil Engineering Writing Project

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Improving Student Writing with Research-based Instruction: Results from the Civil Engineering Writing Project

The Civil Engineering Writing Project, funded by the National Science Foundation's Transforming Undergraduate Education in STEM program (grant no. 1323259), addresses a persistent problem in engineering education: the discrepancy between the writing skills of program graduates and the demands of writing in the workplace. In the project, new teaching materials are based on research about effective writing by civil engineering practitioners. The materials are integrated into existing courses and assignments, rather than through major curriculum changes, so that new instruction can be implemented more easily and quickly. This poster paper provides a brief summary of the project, emphasizing the teaching materials and assessment results from the past three years. More details can be found in several publications [1]-[5].

Project Need, Background, and Objectives

For decades, surveys of alumni and employers have found that writing skills are a major weakness among engineering program graduates [6], [7]. Programs have sought to improve students' writing preparation especially with new types of assignments, improved assessment rubrics, and updated learning outcomes [8]-[10]. Surprisingly, however, little is actually known about the specific characteristics of writing considered effective in engineering workplaces. General characteristics such as "clear and concise" are easy to agree on, but they can mean different things in an industry workplace and an academic journal. Therefore, before the current phase of the Civil Engineering Writing Project, an earlier phase of the project analyzed practitioner and student writing in civil engineering.

The earlier phase of the project, which was funded by the Course, Curriculum, and Laboratory Improvement Program (grant no. 0837776), sought to understand characteristics of effective workplace writing and to identify features of student writing that are most problematic for the workplace. We analyzed effective documents from approximately 50 firms and public agencies and student papers from approximately 70 courses at five universities, examining organization, numerous language features (such as word choices, active and passive voice, and sentence structures), and errors in standard written English. We used interviews of students and practitioners to interpret the textual analyses, understand writers' intentions, and identify the most serious student writing problems. Results are reported in [1]-[5]. Now, the current project uses those results for the following objectives: (1) to develop materials that address the student writing weaknesses, (2) to pilot the materials at universities with diverse student populations, including a historically Black university, a Hispanic-serving institution, and a university with a high percentage of first-generation college students, and (3) to assess the impact of the materials on student writing. The process is summarized in Figure 1. The overall hypothesis tested in the current phase of the project is as follows:

> The writing of students who receive explicit instruction tying writing to civil engineering content and practice will exhibit vocabulary, grammar, and organization that more effectively meet the concerns expressed by practicing engineers for accuracy, precision, liability, credibility and client expectations.

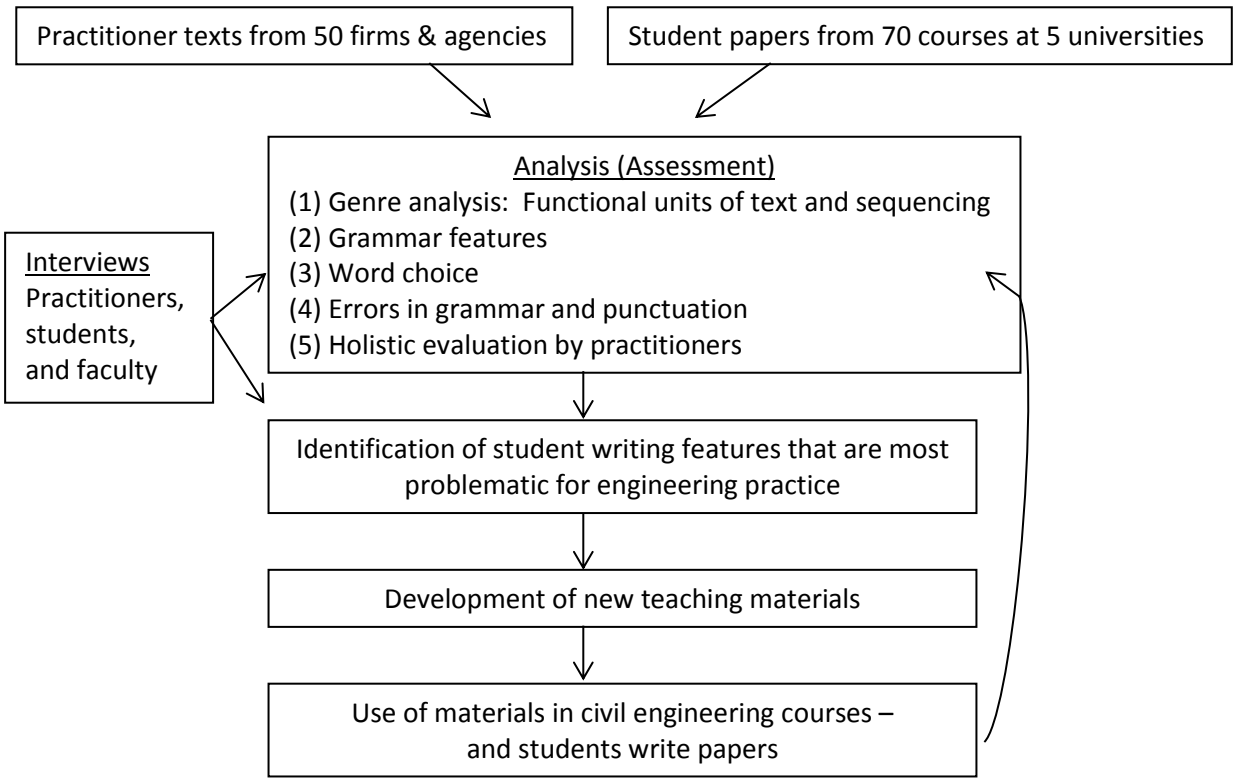

Figure 1. The process of the Civil Engineering Writing Project

The project is based at Portland State University and also takes place at the Cal Poly Pomona, Howard University, and Lawrence Technological University. All offer ABET-accredited degrees in civil engineering and seek to train students to become effective practitioners, but they differ greatly in size, entrance requirements, typical student ethnic and academic background, and technical writing course requirements.

The project has four particularly important features that set it apart from most other writing-related projects:

1) It involves collaboration among engineering faculty, engineering practitioners (in industry), and applied linguists, who specialize in analyzing writing and language functions. The collaboration allows multiple perspectives on student writing weaknesses, student needs, and the design of materials.

2) As described in more detail below, the assessment measures provide multiple perspectives on the materials' impact. They cover words, grammar, and organization. They include quantitative analyses of linguistic features; judgments of the effectiveness of organization and specific features (such as the choice between active and passive voice); judgments of the holistic effectiveness of papers; and student comments in surveys, reflection papers, and interviews.

3) The materials use a functional approach to language. That is, they emphasize to students (and faculty) that words, grammar and organization have an impact on meaning. Effective writing is connected to the accuracy and precision that are hallmarks of engineering, and writing choices are connected to their impact on reader comprehension. The approach thus connects writing with the practice of engineering, rather than describing writing in terms of stylistic choices and conventions that sound arbitrary to students.

4) The materials use a direct, analytical approach for teaching writing. They explain and demonstrate how to make decisions about effective words, grammar and organization. They do not rely on general rules, such as "use logical organization" or "avoid passive voice." They instead provide techniques and guidance with numerous examples so students can start to develop writing judgment. This kind of direct instructional approach has been found to be especially beneficial for students from immigrant and minority groups, who tend not to "catch on" to new writing expectations as quickly as students from more traditional academic backgrounds [11], [12].

Teaching Materials: Design and Piloting

The project has produced three types of written materials. "Genre units" describe the purpose, organization, sequencing, and formatting for typical document types, such as field observation memoranda or geotechnical foundation reports. "Language units" develop students' judgments for choosing effective grammar and wording, covering topics such as effective sentence structures, accurate and precise word choices, and language in e-mail. "Mechanics lessons" address students' 10 most common errors in standard written English and punctuation. Webcasts of 10-15 minutes also accompany the written language units.

The materials are drafted by applied linguists and engineering faculty. Each unit is also reviewed by two engineering practitioners to check that explanations are consistent with engineering practice or that industry and academic contexts are clearly distinguished. The units include the following:

- Examples of effective practitioner writing illustrate the targeted feature with explanations of why it is effective.
- "Myth buster" boxes address misconceptions that students consistently expressed in interviews. For example, a unit on simple sentence structure counters the belief that sentences are more effective if they look complicated and fancy.
- Specific revision techniques are exemplified and explained with examples from real student papers.
- Practice activities cover each specific revision technique and then provide integrated practice using all the techniques.

The teaching materials are designed to be integrated into civil engineering courses that already have relevant writing assignments. For example, the "field observation memo" genre unit is typically used in first-year courses that require students to take field trips and observe construction sites or other projects. The active/passive voice unit is more typically used in higher-level courses where students start writing projects for clients.

The materials have been piloted in approximately 20 courses at the four universities, often over multiple years. Courses have included all four years of study and different specialties within civil engineering. The materials are designed so that they can be used as homework or class activities, and instructors have implemented them in varying ways. Some have writing workshop time during class. Some assign units for homework and have class time for questions and discussion. Some tell students to use certain units to help their writing, but they have no follow-up during class. We anticipate that student writing will improve more if class time is spent with the materials, but thus far preliminary analyses have found no significant differences between courses using the materials in different ways. We hope to investigate the variation between different implementations further in the future.

Assessment Measures

The impact of the materials is assessed from three perspectives: text analysis, practitioners' evaluations, and students' reflections. These three perspectives entail five general categories of analysis, described in Table 1. Three categories of analysis focus on the written texts, comparing pre-intervention and post-intervention papers. The genre analyses assess changes in organization and content sequencing. Linguistic analyses investigate the frequency and effectiveness of specific features targeted by the language units (for example, active/passive voice use, word choices, and sentence structure). The error analysis focuses on the use of standard written English and corresponds to the mechanics lessons. In addition, engineering practitioners do blind ratings for samples of pre- and post-intervention papers and make a holistic judgment of each paper's effectiveness. This step is important because changes in language features or organization do not always correspond to changes in overall effectiveness as viewed by experienced workplace professionals. Finally, the fifth category of assessment asks students for their reflections on the materials through surveys, reflective writing, and interviews.

For the assessment, papers are sampled from the courses using units. The exact number of papers used in the analyses has varied. For example, 198 papers from 7 courses were used to investigate changes in the frequency of passives because the frequency can be analyzed computationally. However, the analysis of effectiveness of passives used only about half those papers because judging effectiveness requires a considerable time commitment.

Overview of Assessment Results

Table 2 provides a summary of results obtained from three years of piloting the units. As the table shows, all the assessment measures have found that the new teaching materials had a positive effect on student writing. This was true for quantitative assessment of discrete language features, such as sentence structure and precise word use; qualitative evaluation of content and organization; and practitioners' holistic evaluation of writing effectiveness.

Table 1. Measures used to compare pre-intervention and post-intervention papers

Assessment Category		Main Features of the Assessment
1	Genre Analysis	• Trained analysts rate presence, effectiveness, and sequencing of functional units of text. (Functional units fulfill purposes such as "provide context for project," "describe methods," and "state recommendations.") • Targets are consistent with practitioner genres. • Analyses are conducted separately for each genre. • Results are analyzed statistically with a Mann Whitney U test.
2	Linguistic Analysis	• Analysis is individualized for specific language features – e.g., sentence structure, word choices, active/passive. • Computer-assisted techniques for quantitative analysis are combined with interpretations of features' effectiveness in context. • Quantitative results are analyzed statistically with appropriate tests depending on distributions and types of features (e.g., with ANOVA, Mann-Whitney U, Chi-squared).
3	Grammar and Punctuation Error Analysis	• Analysis quantifies grammar and punctuation that does not conform to standard written English. • Errors are grouped into 5 categories (sentence structure; verbs; punctuation; typos or spelling; and articles, prepositions and other errors most typical of English as a Second Language writers). • Quantitative results are analyzed statistically with Kruskall-Wallace Analysis of Variance. • Analysis also considers errors' impact on meaning.
4	Holistic Evaluation of Effectiveness	• Engineering practitioners rate samples of student papers using a simple 1 to 5 scale from “not effective” to “effective.” • Results are analyzed statistically with a Mann Whitney U test.
5	Perceptions of Usefulness and Reflections on Learning	• Students complete a short survey about their perceptions of their learning and the materials' usefulness. Alternatively, instructors ask students to write on open-ended questions about their learning. • A sample of students participate in interviews that cover their reaction to the materials. • Survey results are analyzed statistically. Open-ended questions and interviews are analyzed to find patterns in reactions to the materials and suggestions for revisions.

Table 2. Summary of assessment results

Assessment Category		No. of Courses and Levels	Results
1	Genre Analysis (Field Observation Memo, Forensic Analysis Memo, Geotechnical Reports, Cover Letters)	9 courses (first year, junior level and senior level)	statistically significant improvement in effectiveness of rhetorical functions (p <.01)
2	Linguistic Analysis: Sentence Structure	6 courses (first year, junior-level and senior level)	statistically significant reduction in complex sentences (p <.01)
	Word Choices	3 courses (first year and junior level)	statistically significant reduction in vague or inaccurate terms (p < .05)
	Active and Passive Voice	7 courses (first year, junior level, and senior level)	statistically significant reduction of passive voice (p <.05); active voice appropriately used in establishing responsibility
3	Grammar and Punctuation Error Analysis	2 courses (junior level)	statistically significant reduction in grammar and punctuation errors (p < .05) and fewer errors interfering with meaning
4	Holistic Evaluation of Effectiveness by Practitioners	7 courses (all four years)	statistically significant improvement in scores (p < .05)
5	Perceptions of Usefulness – Survey, Reflective Writing, or Interviews	10 courses (all four years)	Survey mode = 3 (on 1-4 scale) "The materials were moderately useful. I learned a few new things and found some practice useful." Patterns in student comments reflect improvement in beliefs about characteristics of effective writing.

Some of the improvements in student writing are exemplified in Table 3. In the geotechnical report genre (example 1), pre-intervention papers often started with unexpected information such as types of data and tests and did not make the purpose of the investigation clear. More post-intervention papers opened with expected information about purpose and identification of the type of project, as in example 1B. Examples 2A and 2B demonstrate the improvement in first-year students' non-technical word choice. Pre-intervention papers had a high frequency of vague words such as "amazing," "great," and "a lot of knowledge." More post-intervention papers used specific words with substantive meaning, such as the use of "informative about the construction and planning portion" in 2B. One of the most pervasive problems in pre-intervention papers was the use of long, complicated sentences that were ambiguous or even inaccurate, as in example 3A. Post-invention papers had a higher frequency of simple sentences with one main idea and

sentences with ideas combined effectively, as illustrated by 3B. Finally, students' overuse of passive voice in pre-intervention papers often obscured responsibility for actions and made sentences difficult to read even when they were grammatical (4A). In post-intervention papers, more students were explicit about responsibility for observations, analyses and judgments, as in 4B.

Table 3. Examples of improvements in student writing

Improvement	Pre-intervention example	Post-intervention example
1. Genre characteristics (sequencing of information)	1A. Opening of report: The report provides data that are based on samples collected from borings using the CPP penetration test. In detail, the report discusses the methods utilized in the geotechnical investigations that are required for the proposal of a two-story structure...	1B. Opening of report: The purpose of this investigation is to explore soil characteristics and subsurface conditions for the design of a footing for a new College of Agriculture building. Laboratory and in-situ tests were completed to obtain...
2. Non-technical word choice (first year students)	2A. The field trip was an overall success I think because it had amazing weather, great tour guides, and a lot of knowledge about engineering. This field trips [sic] are a lot better than sitting in the classroom and you learn a lot more actually going out and seeing how things are done.	2B. This trip to the Tilikum Crossing was informative about the construction and planning portion of civil engineering. Also, it offered me a look at the engineering work being done in the city.
3. Sentence structure	3A. 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).	3B. The Minimal alternative would not remove the invasive grass, which does not process stormwater as effectively as sedum. The Minor and Moderate alternatives would both replant sedum.
4. Active and passive voice	4A. The subsurface exploration and geotechnical engineering services requested for the construction of the College of Agriculture (COA) Building located on the proposed site at Beverly Drive and North Wilson Avenue on the Standard University campus in the City of Carson has been completed.	4B. For excavations to this depth we recommend either sloped walls of not greater than 2H:1V, or shoring...

Student comments demonstrate that the new materials encourage students to re-examine their misconceptions about effective writing and that they appreciate seeing examples of effective practitioner writing. Students often comment on being surprised to learn that they don't "need to be wordy" to write effectively, that practitioner writing has simple sentence structures, and that words need to be precise in engineering, just as calculations are. Student comments have also identified some of the weaknesses of the project – most notably that student papers are sometimes evaluated by graders who have not had writing training themselves, so students get conflicting feedback. One student commented on using a laboratory manual that had incorporated instruction from our active/passive voice unit, which encourages students to be explicit about responsibility for actions (see details in [5]). The student recounted the grader's evaluation of his use of active voice: "I had a little comment that said 'use third person passive,' which is not active voice. So the person grading it was not the person who wrote the lab manual."

Conclusion

Although much more remains to be done to understand effective workplace writing and students' development of writing skills, the results of this project are encouraging. The results are consistent with the hypothesis being investigated: students who receive explicit instruction tying writing to civil engineering content and practice exhibit vocabulary, grammar, and organization that more effectively meet the concerns expressed by practicing engineers for accuracy, precision, liability, credibility and client expectations. Even more encouraging is that improvement does not require major curriculum changes or new faculty. Materials can be incorporated into existing courses and used with existing assignments, helping students do well in their classes in addition to preparing them for workplace writing. The materials from the project are available for downloading at www.cewriting.org.

The effectiveness of the project has depended greatly on the three-way collaboration of engineering faculty, engineering practitioners, and applied linguists. It can take some time to learn to communicate effectively with each other, but this approach benefits from the incorporation of academic and industry expertise, and engineering and language expertise. Given the results within civil engineering, and the needs of other branches of engineering to prepare their students for industry practice, we hope other faculty will be inspired to pursue such collaborations to learn about effective writing in industry and to help improve students' preparation for it.

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