AC 2007-601: HOW ENGINEERING STUDENTS LEARN TO WRITE: THIRD-YEAR FINDINGS FROM THE ENGINEERING WRITING INITIATIVE

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How Engineering Students Learn to Write: Third-Year Findings of the UT-Tyler Engineering Writing Initiative

Abstract

The Departments of Electrical Engineering and English of the University of Texas at Tyler are in the third year of the Engineering Writing Initiative (EWI), a four-year longitudinal study investigating how engineering students learn to write, how they apply these skills in their studies, and how instructional practice can be reconfigured to better develop these skills. The questions which form the charter of EWI are:

- What are engineering students' attitudes, practices and skills with regard to writing, and how do those attitudes, practices and skills develop over time?
- Does writing in engineering courses help students become more involved with those courses and understand and apply the ideas of those courses?
- How can we incorporate we learn about students' attitudes, practices and skills in order to improve our instructional practice with regard to writing?

EWI employs multiple data-gathering methods (semi-annual writing prompts, individual interviews with students, written surveys of students, and student writing samples gathered in portfolios). It employs several assessment strategies (quantitative analyses of student writing samples, quantitative analyses of written surveys, and qualitative analyses of interview transcripts).

Background

The EWI began in 2004 with the our shared sense of frustration over the quality of student writing skills in engineering coursework. Unprofessional language, poor grammar and spelling, badly-formatted tables, figures, and graphs, and data reported without any sense of context: these and many other problems were endemic in the UT-Tyler engineering program. We attempted to address these concerns with the publication of a style guide,[1] yet the changes brought about by that tool were cosmetic, at best. The first year of this project gave us a clearer view of why this might be so: first-year students clearly did not understand writing as relevant to their work as engineers. This understanding was shown to have been augmented somewhat in the second year of the EWI, when we found that the sophomore-level students surveyed had become increasingly aware of writing not only as a means of transcribing data but also as an integral factor in learning course material. In their presentation to this meeting in 2006, we underscored Norback's belief that because these students are becoming members of "discourse communities," or groups of researchers and practitioners sharing a common language of expertise, they should be provided "ample opportunities for 'situated learning' within 'high functional contexts.'"[2] This paper is the third in a series of four planned EWI reports, and will describe these students' further development and maturation as writers, with a particular emphasis on how findings may affect instructional practice with regard to writing.

Methodology

We continue to gather data, and results shown below should therefore be considered tentative. Student access continues to be an issue, now as in last year's report. The work of fifteen freshmen was studied during the 2004-2005 academic year; nine sophomores participated during the 2005-2006 academic year. To date, the work of seven students has been reviewed during the current 2006-2007 academic year.

We continue to use the following tools to gather a variety of quantitative and qualitative information about students' perceptions of their own writing skills and students' abilities as writers:

- A Likert-scale survey of attitudes toward writing;
- A written questionnaire addressing the role of writing in Engineering courses and students' processes and backgrounds as writers;
- Focus-group discussions with students; and
- A quantitative, multiple-trait assessment of writing samples (primarily lab reports).

Results of Likert-scale attitude survey

The Likert-scale survey presented students with statements about the role of writing in engineering courses and asked them to give responses on a scale of 1 (strongly disagree) to 5 (strongly agree). The table below summarizes the percentage of respondents who agree (rating 4) or strongly agree (rating 5) with the statements. A discussion of the results follows Table 1.

Table 1. Summary of Likert-scale attitude survey results from fall, 2006

Statement	2004-2005 (*n*=15)	2005-2006 (*n*=9)	2006-2007 (*n*=7)
I'm an experienced writer.	60	66	?
Writing in Engineering courses helps me understand the course material.	53	77	57
I care about the writing I do in Engineering courses.	80	88	86
Writing plays an important role in Engineering courses.	80	88	57
I spend a great deal of time on writing assignments in Engineering courses.	46	62	71

Discussion of fall 2006 attitude survey

Reponses to the attitude survey should be viewed with caution for several reasons. The sample size is small. As noted above, the researchers acknowledge great difficulties in encouraging responses and acquiring data from EWI participants. In addition, several original participants in the study have left their engineering programs. Finally, some of the respondents' answers were invalid, as they did not pass the survey's simple test for internal consistency. For example, in response to the prompt, "In general, I'm an experienced writer," one EWI participant listed agreement (4); yet in response to the prompt, "In general, I'm an inexperienced writer," the same participant also listed agreement (4). The extent of these invalid responses surprised the researchers, who found that every participant included at least one such response in his or her survey. This is why the 2006 survey results show "?" for the question of being an experienced writer. No such problems with internal consistency were found in previous years' studies.

The problem with internal consistency also disqualified three respondents' answers to the fourth prompt, "Writing plays an important role in engineering courses." The researchers expected responses to this prompt to be consistent with responses to the third and fifth prompts, which ask EWI participants to gauge the "care" and "time" they take with their writing assignments. With these prompts, the majority of participants agreed that they "spend a great deal of time working on writing assignments in [their] engineering courses," and they "care about the writing they do as part of [their] engineering courses." These two findings appear consistent with participants' responses to the written survey and focus group discussion, noted below. Indeed, these responses show that study participants are investing more time and effort in their written work.

The percentage of participants agreeing or strongly agreeing with the statement, "Writing in engineering courses helps me better understand course material," declined from the previous year's study to a level slightly above the percentage noted in the inaugural year of the EWI. The researchers believe that this may be due to several respondents' invalid responses to the survey prompts. With an increased number of invalid responses, the percentage of valid responses declined.

Results of written questionnaire

During the 2006-2007 academic year, students involved in this study were asked to complete a written questionnaire in which they discussed several aspects of their writing in Engineering classes. The questionnaire is intended to reveal students' views on the role of writing, the process of writing, past and present preparation for writing, and the role of style guides.

The questions included in the survey are as follows:

1. What are you learning this semester in your Engineering classes that seems the most valuable to you?
2. Has writing helped you to better understand what you've learned in question #1? If not, has writing helped you understand any of the course material in your Engineering classes?
3. What do you believe is the function of writing in Engineering classes? Explain.

4. What writing strategies or techniques do you use as you write in your Engineering classes?
5. What has best prepared you to write for your Engineering classes? An instructor, tutor, past or present writing class, etc.? Explain.
6. Do any of your professors use a style guide? If so, what role does it play in your writing?
7. Describe the writing process(es) you follow in your Engineering classes.

All students surveyed demonstrated that writing indeed plays a key role in helping them comprehend the discipline-based knowledge indicated in question one. This was true of even the most cursory response, in which one student said that taking notes in class helped him better understand heat transfer. Other responses indicated students' awareness of the role writing plays in "communication" and "understanding" of course materials. One student wrote that "all the writing involved in this class gave me a broad idea [about] the technical writing that professional engineers do on a regular basis."

Students demonstrated their understanding of the role of writing in engineering classes was evolving: an idea that is further developed in the "Focus Group" section, below. The function of writing, for these students, is clearly not limited to information transfer. It is a way of shaping experience, creating possibilities. "Technical writing helps display ideas and plans when images and figures will not help," wrote one respondent; "writing helps to explore and invent new ideas [and] it helps [me] to think outside the box," wrote another. One student showed a keen rhetorical awareness in noting that "since the target audiences can vary from experts in the subject to non-experts…it is crucial to learn to assess all parameters involved in writing a document that will satisfy readers' expectations."

With regard to process, respondents tended to communicate in terms of linear trajectories, from brainstorming, research and data-gathering to drafting to editing. Writing was not depicted as an inherently complex act in this regard, although respondents did to some extent indicate care and deliberation: "After all the writing is done," one student noted, "I usually go through the document three or four times to make sure the content is relevant to the topic covered."

Respondents also noted that some of the best preparation they have had for current writing tasks has come not only from past writing classes, but also templates in the form of style guides and "strict guidelines" provided by instructors in engineering classes.

Discussion of written questionnaire

With regard to the role of writing for student writers, Sommers and Saltz[3] have indicated that the strongest student learners tend to "see in writing a larger purpose than fulfilling an assignment" (p.124). Certainly this is true of the junior-level EWI cohort, some of whom understand that the kind of writing assigned in class will be the kind of writing required on the job. With regard to the process of writing, Lindemann[4] cautions against overly "simplistic" and reductive models of writing, which "do not account for individual differences among writers" and "do not appreciate the complex intermingling of activities, decisions, constraints, and goals writers juggle" (p. 31). Accordingly, we suggest, now as in the past two years, that some students surveyed still do not understand the complexity of the writing tasks assigned them. This may play a crucial role in some students' apparent inability to draft stronger prose. With regard to preparation for writing, we hold with Reither[5] that writing is essentially a social and rhetorical task: occurring in communities of other writers, all of whom work under conditions and in pursuit of goals that, ideally, transcend the classroom setting. This kind of sophisticated awareness of rhetorical agency and exigency is evident among some students surveyed. Style guides, finally, appear to be appreciated by students as powerful means of sharing disciplinary standards for written documents. This will have implications in terms of pedagogical and curricular changes.

Results and discussion of focus-group discussion

Early in the Spring semester a focus group of four students from the EWI cohort gathered to debrief. The following questions were asked:

- Looking back, what do you now wish you had known about writing in engineering courses when you entered the program?
- How are you learning to write like an engineer?
- Is writing you do in engineering courses a vehicle for learning? For contributing to knowledge in the field?

With regard to the first prompt, study participants noted that they detected key differences between the writing they had completed prior to entering the University's engineering program, and the writing they had completed since. Prior writing, for them, appeared more subjective, with questions such as "How does this appear *to you*? [emphasis mine]" paramount. Engineering writing worked in a more "objective" manner, with questions such as "What was this measurement?" as the primary focus. The researchers suggest that these responses corroborate much of what is known through widespread WAC (writing-across-the-curriculum) practice. Writing proficiency within a given discipline is created by writing within that discipline.

Participants reported that they learned and are learning to write like engineers by making mistakes; by following outlines and formats; and by using specific style guides. To the follow-up question of what engineering professors might do to improve the teaching and learning of writing, participants unanimously agreed that standards for good writing must be clearly articulated. Asked if courses in other disciplines might have prepared them to write for Engineering classes, participants were in general agreement that such writing had little bearing on their coursework. This, again, confirms what Norback has noted, above, with regard to the efficacy and relevance of discipline-specific writing practice.

The third question, which encouraged students to consider if writing served an educative purpose in terms of both student and discipline, was met with a variety of responses. "When we write, we connect knowledge to theory," noted one student. Another student added, "Writing is something that helps you understand what you do: in reports, you are trying to convey information [and] teach information." This was met with unanimous support; as one participant noted, "The best way to learn is to teach." Such responses are consistent with Sommers and Saltz's conceptions of mature student learners, as noted above.

Results of multiple-trait assessment of writing samples

Junior-level students from the EWI cohort were asked throughout the 2006-2007 academic year to provide writing samples from their coursework. These writing samples consisted primarily of laboratory reports, and were evaluated according to the following criteria:

- Organization: Written material is organized appropriately into discrete units-for example, title page, project description, methods and materials, results, discussion, conclusion, and references.
- Content: Written material is presented in paragraphs, each of which is focused on one topic. Written material is also coherent, with strong transitions between ideas. Written material is well-developed, in that the writer fully explains, describes, summarizes and/or analyzes, as needed. Finally, equations are relevant and necessary to the development of the written material, with all variables clearly defined.
- Mechanics: Written material adheres to all relevant conventions of grammar, punctuation and spelling. Equations are formatted correctly; fonts are uniform; scientific notion is accurate.
- Professional language is employed. Slang, colloquialisms, first person, second person, and the imperative mood are avoided. Primary emphasis is on a replicable process or experiment, not a personal account of an activity.
- Tables, figures, and graphs: All tables, figures and graphs are well-formatted, comprehensible, and used appropriately.
- Technical merit: Material is free of errors in technical matters.

We independently assessed the examples and assigned scores in all categories except technical merit for each work, using a scale of 1 (strong disagreement) to 5 (strong agreement). (Technical merit was scored by engineering faculty member Dr. Beams alone). Each paper was read and scored independently, and the median value of the rating of each student's work was determined for each evaluator. Figure 1 below shows the results for each evaluator for fall, 2006 and contrasts these with the results for fall, 2005.

Discussion of multiple-trait assessment of writing samples

The results contain reasons for both optimism and pessimism. We make the following observations from Fig. 1:

- Organization was noticeably improved; this could probably be attributed to the fact that all assignments in this sample were laboratory reports were apparently created using standardized guides or templates.
- Neither author noted much change in the quality of the content of laboratory reports. This is somewhat surprising, given the expectation that students at this level would be adapting to the idiom of their professional communities of discourse. A possible explanation is that wide discrepancies in participants' writing samples were noted, and this range of responses was reflected in the overall rating.
- Evaluations of mechanics showed problems with consistency in tense; the imperative (rather than declarative) mood used to describe experimental processes; comma splices

and run-ons; spelling; capitalization; and appropriate bibliographical format. It should be noted, however, that these errors were not found in all materials evaluated.

- Language was professional in tone throughout the majority of the samples (only two of the samples showed unprofessional tone).
- Both evaluators agree that the area showing the greatest degree of weakness in both 2005 and 2006 is the use of tables, figures, and graphs. This will be described in greater detail below.

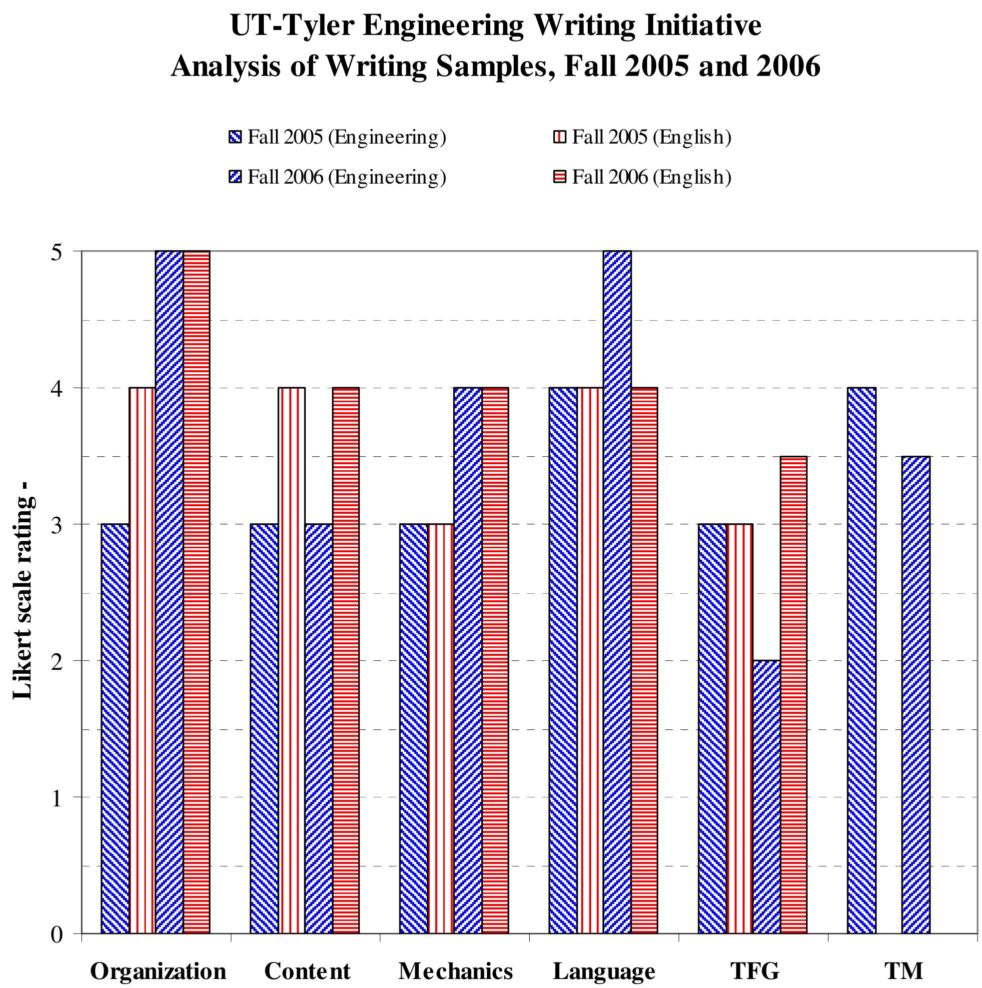

Figure 1. Results of assessment of engineering writing samples from 2005 and 2006. The label "TFG" is an abbreviation for "tables, figures, and graphs;" "TM" means "technical merit."

All of the reports read contained some degree of problem in the use of tables, figures, and graphs. These ranged from minor stylistic problems (font in graphs and figures did not match text) and legibility problems (image too small or not legible when printed on a monochrome printer) to significant (e.g., confusing axis labels or unlabeled axes) or, in one case, incorporation of graphs apparently scanned from a published source. There appear to be a number of factors at play in the continuing problems with tables, figures, and graphs. Frequently, students will express experimental results in tabular form even when the information in these tables is obscured by their sheer length. This may be a simple matter of convenience; it is arguably less work to create a table in Microsoft Word and type one's data directly into the report than to create graphs of these data with Excel. It also appears that students who do create graphs with Excel will accept its default formatting, even if such formatting is not optimal.

The Pearson product-moment correlation of ratings of 2006 writing samples is 0.74, representing positive to strong-positive correlation.

As noted previously, the data represented in Fig. 1 are *median* scores. Scores of 5 by both evaluators in Organization do not mean that *every* sample submitted earned an exemplary score for this trait. The table below summarizes the *mean* ratings of the 2006 literature sample as scored by both Drs. Niiler and Beams. Comparison of these ratings shows that the evaluators were in good agreement in their ratings.

Table 2. Comparison of mean ratings per trait of the 2006 EWI literature sample.

Evaluator discipline	Organization	Content	Mechanics	Language	TFG
English	4.1	3.4	3.5	3.9	3.1
Engineering	4.3	3.1	3.6	4.0	2.4

Curricular application of the findings of EWI

Some tentative conclusions concerning curricular application of the findings of EWI may be drawn.

Students in the EWI cohort generally see the role of writing in their engineering coursework as positive or beneficial. However, they initially tended to over-rate themselves as competent writers, and it is only after some experience that their somewhat-naïve confidence is diminished. It goes without saying that opportunities to write within engineering disciplines should be embedded throughout the curriculum.

Comparison of freshman work with later work of EWI students has demonstrated improvement in most areas described by our evaluation rubric. However, the use of tables, figures, and graphs remains problematic, chiefly because of lack of care in their preparation or their use with little or no introductory text. Dr. Niiler, who works with student writers at all levels of proficiency and in several disciplines, suggests that this is a shared problem. Students often insert not only tables, figures and graphs, but also secondary source materials such as quotes, with little regard to how those materials support, constrain, interrogate or make problematic their arguments. Rhetorical problems remain common; for example, the introduction of a laboratory report makes reference to "previous labs" with no link to what these might have been. In another place in this same report, the author attempts to validate experimental findings with published data in the form of a graph which appears to have been scanned from a textbook (and for which no attribution was given). The published data include *two* variables plotted on the same set of axes, only one of which is relevant to the report. The presence of the additional variable is neither mentioned nor explained in either the text or the caption of the figure, and can only confuse the reader with irrelevant detail. In two cases, reports used figures as SEPPs ("Self-Evident Pretty Pictures," figures that convey meaning without further explanation or elaboration). In sum, we conclude that the principal weakness shown through EWI is a lack of *design of technical writing as a means of transmitting information.*

It seems evident that expectations of the caliber of written communications expected from engineering graduates must be clear to both students and to faculty. However, as the work of Hirsch et al demonstrates, students and faculty may hold significantly-different perceptions of what constitutes "commonly-shared standards" even when both agree that such standards exist.[6] This work finds the greatest differences between faculty and student perceptions exist in the importance of mechanics: grammatically-correct sentences and spelling and punctuation. Faculty agreed these to be valued characteristics of engineering writing, whereas students were essentially neutral. The greatest agreement is in the importance of clarity in technical matters.

However, while engineering faculty may value good style and mechanics in their students' writing, they do not see it as their place to *teach* such subjects. Some of our engineering colleagues have stated that they will circle egregious grammatical, spelling, or punctuation errors in written assignments, but will otherwise focus on technical content. This is understandable; engineering faculty are typically not trained to teach and evaluate technical writing, and effective teaching and evaluation of student technical communication appears to require active collaboration between engineering and writing faculty.[7] This collaboration already exists in the UT-Tyler engineering program in a limited sense: one writing faculty member will visit two or three engineering professors' classes during the course of a given semester to promote and illustrate strong writing skills. Engineering students are in turn invited to utilize the University's Writing Center, where trained tutors are available to assist them.

A standardized style guide appears to be a response to problems of mechanics. As is shown above, such a style guide, when used, is appreciated by students. However, the most-significant problems appear to be those of *rhetoric* and *logical construction*, not necessarily of spelling and grammar. And these are problems for which a standardized style guide does not appear to be effective.[8]

In light of the above, we are developing a pilot program called "Design for Communication" that regards creating effective technical communications as a design process closely allied to the engineering design process itself, a concept developed by Sorby and Bulleit.[9] The design of a circuit or system lies within a solution space whose boundaries are determined by such considerations as function, feasibility, user needs, and affordability; the design of technical communications lies within a solution space bounded by audience, nature of the communication, intended effect, and existence of standardized models or formats. In our present thinking about Design for Communication, we plan to have students provide written answers to the following discussion questions, or heuristics, before beginning to write technical reports:

- Audience: What is the intended audience? (Supervisor, colleagues on the same project, colleagues working on different projects, technically-trained audience unfamiliar with the details of the project, non-technical adult audience, children)
- Purpose: What is the purpose of this report? (Publish new findings or novel designs; provide information to management for decision-making; give technical information to colleagues; establish instructions for processes or procedures; arouse curiosity)

- Formality: What is the expected degree of formality? (Published journal; formal laboratory report; memorandum; informal note)
- Bibliographic depth: What is the expected use of external references? (Published journal, with multiple references; formal laboratory report, possibly with external references; memoranda or informal notes generally lacking external references)
- Theoretical depth: how detailed must the theoretical background be? (Extensive—several pages and numerous equations; moderate—one or two pages, some equations; light—less than one page and one or two equations; none)
- Standard format: Is there a recognized de facto or published standard format?
- Template: Is there a mandated or recommended template or blank form?

We propose not another rubric but the above heuristics, means of helping students understand that the writing they are asked to do for Engineering courses is contextual, or highly situated within a frame of disciplinary values, discussions, and expectations. Because these questions address highly contextual issues, the answers will, in fact, vary according to assignment, audience, and content.

An initial effort is underway at present in a junior-level electronics laboratory course. Students are required to submit a written "checklist" prior to undertaking an assigned laboratory exercise in which questions of audience and appropriate form of the communication must be answered.

Conclusion

We have documented the maturation as writers of the cohort of EWI students and have identified what we believe to be the weakest link in the process of engineering writing. We plan to respond by providing students with a conceptual framework to see communication as a design process in its own right, which we believe will be a step toward addressing the rhetorical deficiencies that often characterizes engineering writing by students. It is hoped that providing students with a conceptual framework to see communication as a design process in its own right will be a step toward addressing the rhetorical deficiencies that characterize frequently encountered in student work we have reviewed.

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