Session 3432

# Improving Technical Writing through Published Standards: The University of Texas at Tyler Electrical Engineering Laboratory Style Guide

**David M. Beams**
**Department of Electrical Engineering, University of Texas at Tyler**

**Lucas P. Niiler**
**Department of English and Writing Center Director, University of Texas at Tyler**

Abstract

The writing of technical reports is an integral part of the duties of practicing engineers. The accreditation criteria of EC2000 recognize this by placing emphasis on "soft skills" in engineering education, including written communication skills. Written reports in laboratory classes in electrical engineering at the University of Texas at Tyler have been required since the inception of the engineering program in 1997, but the low quality of written reports produced early in the history of the program made it apparent that engineering students lacked the ability to construct coherent reports. The response to this problem was the development of a published Laboratory Report Style Guide to which written laboratory reports are now required to conform. This paper traces the development of the Style Guide, describes its use in the curriculum, and documents the improvements in student writing realized through its use.

## Why a Style Guide was Necessary

The School of Engineering of the University of Texas at Tyler (UT-T) opened in summer, 1997 and began teaching full course offerings in electrical and mechanical engineering that fall. The UT-T was an upper-division school at that time; all students entered the university as transfer students, typically at the beginning of the junior year. (The university began enrolling freshmen and sophomores in fall, 1998, but transfer students still form a significant proportion of the engineering student body). All of the students in the first cohort thus had had at least two years of college coursework prior to matriculation at UT-T; two of them had previously earned BS degrees in physics at another Texas state university. All had taken a minimum of two semesters of English grammar and composition and completed at least one semester of general chemistry, two semesters of physics, and an introductory circuit-analysis course before enrolling in the BSEE program at UT-T. All had had laboratory experience in their coursework.

It might be assumed that students having such credentials would be able to write coherent reports of their laboratory work. The first laboratory reports submitted in the fall of 1997 immediately dispelled this assumption; their overall quality could best be described as abysmal. There were numerous mechanical problems (spelling, punctuation, grammar, and page formatting), but worse than these were widespread problems of logical organization. The typical narrative of a report was something like "We measured the frequency response of the first circuit, and here is what we got." There was little or no description of procedure, theoretical background, or comparison of results with expectations. There were even ethical problems in some reports. As an example, one laboratory group submitted a report on the frequency response of passive networks in which they substituted results of circuit simulation for the required empirical measurements. (It was easy to see through the deception because they presented results at frequencies up to 1GHz, whereas the lab generators' maximal frequency was 15MHz). It was not clear whether they had botched the experiment, lost their data, or simply decided that doing the lab procedure was too much work.

In response to the poor quality of the original lab reports, Drs. David Beams and Allen Barger developed a one-page summary how to prepare laboratory reports. This summary attempted to set some structural and style requirements for all lab reports. The one-page summary was used for the 1997–8 academic year.

Experience with the one-page summary in practice showed its inadequacy. Students needed more guidance in organizing, formatting, and writing their reports. Some examples may be illustrative. The summary stated that the tone of the report should be professional and colloquial writing was to be avoided. This did not prevent one student from describing the measured gain-bandwidth product of a high-speed operational amplifier in the following terms: "Compared to a 741, this circuit was a screamer." The summary also required reports to be written in the third person. Another student complained about the low grade on a particular laboratory report. It was pointed out to him that his "Experimental Procedure" section was simply copied *verbatim* from the laboratory assignment and this part of his report was therefore written in the second person, imperative mood. The student (who held a BS in physics) responded, "What do you mean by 'second person?'" (The ethics of plagiarism apparently did not enter into consideration for him). The dismal situation required positive corrective measures; the style guide was one response.

Development of the UT-Tyler EE Laboratory Style Guide

The first version of the UT-Tyler EE Laboratory Report Style Guide was inspired by a writing style guide for engineers developed at the University of Wisconsin. The UT-Tyler Style Guide was published by Drs. David Beams and Allen Barger on Aug. 20, 1998 and was first used in fall, 1998. It remains in use (with modifications) to the present time.

The 1998 Style Guide can be diagrammed as shown below. It consists of a section of guidelines for writing laboratory reports and an appendix which is an outline of a laboratory report. This structure, with some modification, remains in use in the most-recent version of the Style Guide.

**General Guidelines for Writing Laboratory Reports**

I. Introduction
II. Specific style guidelines
    Tone and style

Use of figures
Equations
Tables
Units
Reference citations

**Appendix: Outline of a Laboratory Report**

I. Project Description
II. Methods and Materials
    Equipment
    Experimental procedure
III. Results
IV. Discussion
V. Conclusions
VI. References

The Appendix (Outline of a Laboratory Report) is intended as a template for student laboratory reports. Students may use the template by opening the Style Guide (which is available to them on the UT-T engineering file server), stripping off the General Guidelines section, and replacing the text of the Appendix sections with their own text.

Examples from the Style Guide

The examples below are taken from the general guidelines for writing laboratory reports.

- Written communications should reflect a professional approach to technical content and style. Avoid colloquial expressions; for example, "The prototype operational amplifier had much greater gain-bandwidth product and slew rate than an LM741" is acceptable; "Compared to a 741, this circuit was a screamer" is *not*.

- The engineering laboratory report should be readable by a person who is technically trained but not necessarily familiar with the experiment. That person should be able to replicate the experiment after reading the laboratory report.

- Write in third person. "I," "we," and "you" are *not* to be used in a laboratory report. Nor is the second-person imperative mood to be used (e.g., "Measure the voltage gain of the common-emitter amplifier").

- A title page must be included. All pages except the title page must be numbered sequentially, beginning with "1." Page numbers are to be at the bottom of the page, centered or right-justified.

- All diagrams, illustrations, and graphs *except* tables are called "figures." Graph axes must be labeled legibly and units must be specified (e.g., mV, A, Ω, kHz). Each figure



*Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition*

must be cited in the report text. References to figures in text are of the form "Fig. 1," but the word "Figure" is not abbreviated when it is the first word of a sentence. All figures are to be numbered sequentially. Figures will be computer-generated and embedded in the report text whenever possible. Figures must be centered and must be contained on a single page. Figures also must have captions that are left-justified or full width (*not* centered). The entire caption *must* be contained with the figure on the same page.

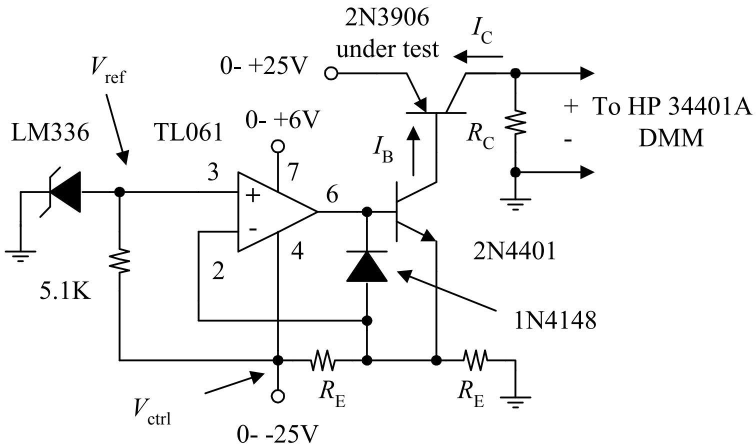


Fig. 1. Test circuit for measuring the $I_C$ vs. $V_{CE}$ characteristics of a 2N3906 PNP transistor. Values of emitter resistors $R_E$ and collector resistor $R_C$ are given in the text. Currents $I_B$ and $I_C$ are respectively the base and collector currents of the 2N3906 transistor under test. Voltage $V_{ctrl}$ (supplied by the 0- –25V output of the HP E3631A) controls $I_B$. $V_{ref}$ is the voltage at the anode terminal of the LM336 voltage-reference device.

The following example is the text of the Project Description section of the Appendix.

**I. PROJECT DESCRIPTION**

This section should tell <u>*why*</u> the experiment was performed. The purpose involves specific principles, circuit topologies, and/or measurements. These need to be <u>*explicitly*</u> stated. It is <u>*not*</u> sufficient to say that "The purpose of the experiment was to familiarize the student with non-ideal behavior of operational amplifiers." An acceptable form would be "This experiment examined the effects of non-ideal characteristics of operational amplifiers on simple inverting-amplifier circuits. Specific non-ideal characteristics include limited gain-bandwidth product, limited slew rate, nonzero input-bias currents, and nonzero input-offset voltages."

Amendments to the Style Guide

Minor changes were made to the Style Guide in August, 1999, December, 2001, and August, 2002. Significant changes were made in January, 2003 to address persistent problems in student laboratory reports:

- "Self-evident tables": students would frequently present experimental results in the form of tables even when the data consisted of many points. A section was added to show the

comparison of the same data presented in a table, a badly-formatted graph, and a well-formatted graph.
- Unwarranted precision in calculations: students would almost always present calculations with as many decimal places as were produced by their computers. A section concerning proper use of significant digits was added to address this problem.

An example report was written as a supplement to the Style Guide in July, 2003.

Use of the Style Guide in Laboratory Courses

The EE Laboratory Report Style Guide has been used chiefly in EENG 3106 (Electronic Circuit Analysis I Lab), EENG 4109 (Electronic Circuit Analysis II Lab), and EENG 3104 (Electric Circuit Analysis I Lab). Students will typically write six laboratory reports in a semester in these courses. Typically two or three laboratory reports will be designated as "formal" lab reports for which both drafts and final reports are required; only the final reports are required for other laboratory exercises. Formal reports require all sections specified by the Style Guide be present; other laboratory reports may not require all sections. The minimal requirements for any report are the Project Description, Theoretical Background, and Results.

Assigning numerical scores with some degree of objectivity has been an elusive task, particularly concerning style, format, and organization. A score sheet with rubrics has been developed to give structure and consistency to the process. Reports are evaluated for both technical content and for style, formatting, and organization.

Does the Style Guide Improve Technical Writing?

Assessment Methodology

The authors undertook an assessment to understand the impact of the Style Guide on lab reports. The assessment methodology employed followed a model previously used by Dr. Niiler in the UT-T English Department [1] and in the UT-T Writing Center (2003).

Forty-four electrical engineering lab and project reports were collected in one volume in December, 2003. Twenty-three reports were written by students who had been required to follow the Style Guide in class, and 21 reports were written by students who had not been required to do so. The question guiding the authors' assessment was, "To what extent did the Style Guide affect the quality of finished lab reports?"

Reports prepared by students with Style Guide exposure were termed "experimental," and those reports prepared by students without this exposure were termed "control." Names were removed and marks were erased to create clean copy. All reports were given random codes, and three copies of each lab report were produced. The reports were then collated into three hardbound notebooks. Each notebook contained the same reports in randomized order**.** Three experienced readers not affiliated with the College of Engineering were asked to rate the lab reports in a blind read. Before beginning their readings, the readers participated in a norming session in which they were introduced to the evaluation criteria for the reports. The session also included a trial blind read in which discrepancies among individual readers' interpretations and applications of evaluation criteria were addressed by Dr. Niiler. The evaluation criteria listed immediately below were developed jointly by the authors. Dr. Niiler also consulted a science portfolio assessment guide published by the Florida Department of Education [3].

1. Format: The lab report adheres to organizational criteria as mandated by the Style Guide: i.e., it includes a title page, project description, theoretical background, methods and materials, results, discussion, conclusion, and references.

2. Function: Each section of the lab report is unified, with no extraneous materials; coherent, or written in a logically sound manner that moves the reader seamlessly from one sentence, and section, to the next; and well-developed, or written in a manner that sufficiently explains and discusses the topic at hand.

3. Mechanics: All applicable conventions of grammar, spelling and punctuation are in evidence.

4. Language: All language is professional, appropriate to the discipline. No colloquialisms or slang are used; the first and second person are avoided; the imperative is likewise not used; and the primary emphasis of the lab report is on a replicable process or experiment, not a personal account of an activity.

5. Tables and figures: All tables and figures abide by the guidelines established in the Style Guide.

Each lab report was scored on a Likert scale, which asks readers to indicate the degree to which they agree or disagree with a series of statements on a scale of one to five. Five indicates strong agreement; four, agreement; three, not sure; two, disagreement; and one, strong disagreement. For example, under "Format," readers considered whether they strongly agreed, agreed, were not sure about, disagreed, or strongly disagreed with the statement, "The lab report adheres to organizational criteria as mandated by the Style Guide." Readers followed the same procedure for all criteria on all lab reports.

The arithmetic mean of each reader's scores by individual criteria were calculated to compare ratings between control and experimental groups. Standard deviations of individual readers' ratings were also calculated to determine the spread of the scores assigned by each reader; ideally, readers would not show a large variation within their scoring. Finally, the researchers used the consensus estimate method of determining inter-reader reliability; this method can be used in conjunction with the Likert scale [4]. Consensus estimates were calculated by deriving a percent-agreement figure for each criterion among the three readers. For each of the above criteria, the number of lab reports with agreeing scores was divided by the total number of lab reports. The researchers worked with a common, broadened definition of "agreement," as noted in [4]: if two readers scored a given criterion within one point of each other, they were considered to have reached agreement.

It should be noted that the readers were not in contact with each other during the reading, nor did the readers know which lab reports had been prepared with the Style Guide, and vice-versa. All copy was clean and no reader had any knowledge of any student's grade or professor's comments.

Results

A. Mean Scores

As can be determined from Figs. 1-3 below, each reader gave higher scores to reports from the experimental than to reports from the control group.

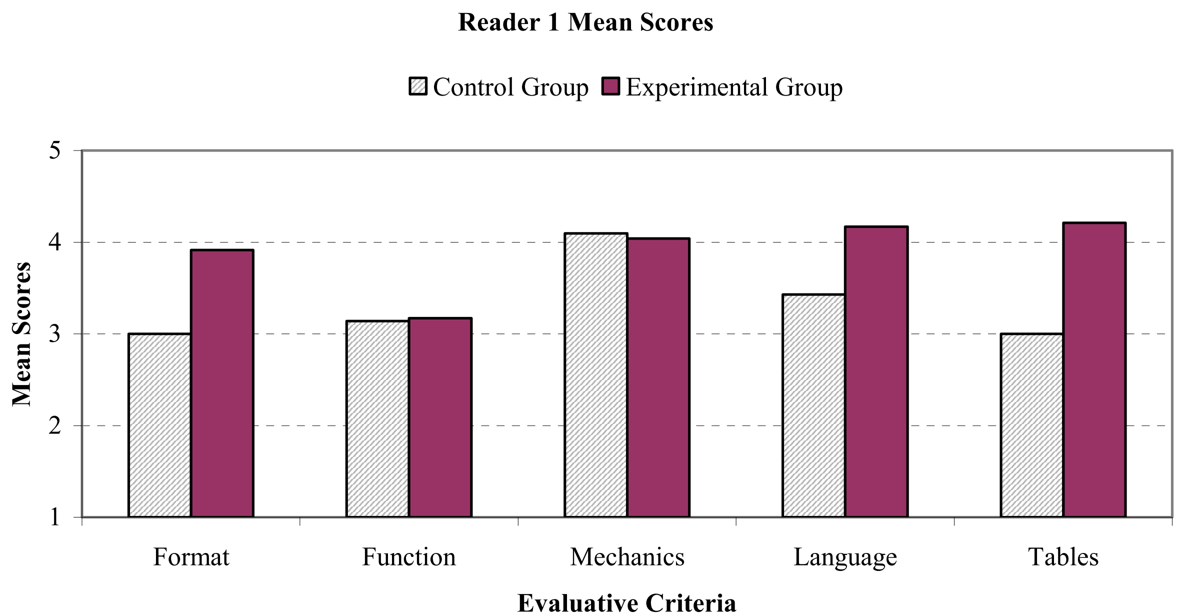


Fig. 1. Scoring of reports by Reader 1

Results from Reader 1 are shown in Fig. 1 above. In terms of criteria evaluated, Reader 1 recorded the following: in criterion #1 (Format), an increase from control to experimental of 0.9; in criterion #2 (Function), an increase of 0.03; in criterion #3 (Mechanics), a decrease of 0.05; in criterion #4 (Language), an increase of 0.7; and in criterion #5 (Tables and figures), an increase of 1.2.

Results from Reader 2 are shown in Fig. 2 below. In terms of criteria evaluated, Reader 2 recorded the following: in criterion #1 (format), an increase from control to experimental of 1.0; in criterion #2 (function), an increase of 0.50; in criterion #3 (mechanics), an increase of 0.70; in criterion #4 (Language), an increase of 0.70; and in criterion #5 (Tables and figures), an increase of 0.90.

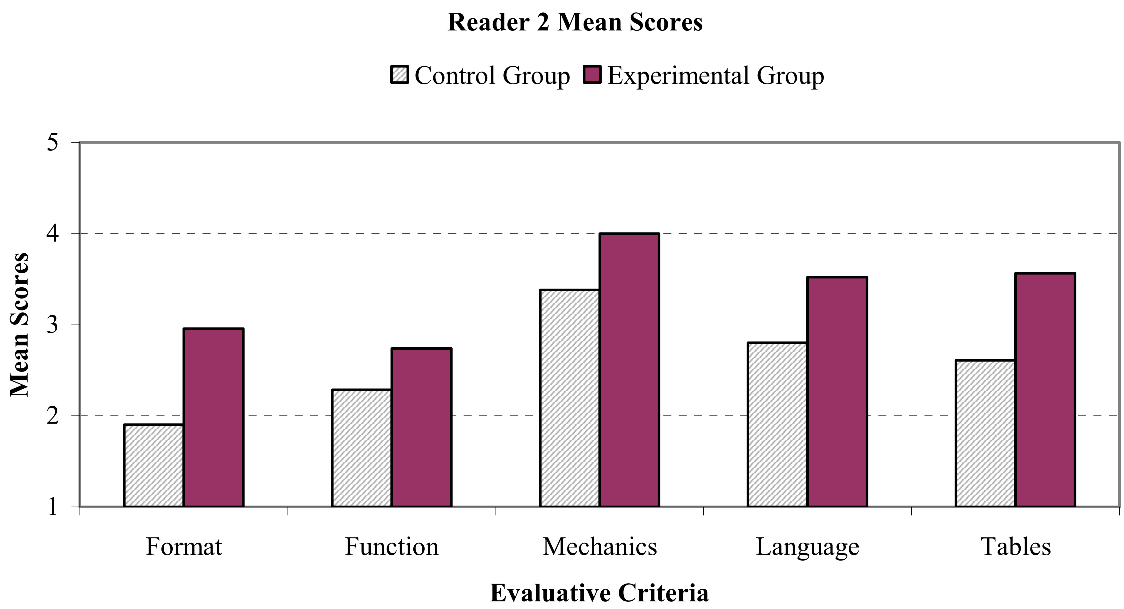


Fig. 2. Scoring of reports by Reader 2

Results of Reader 3 are summarized in Fig. 3 below.

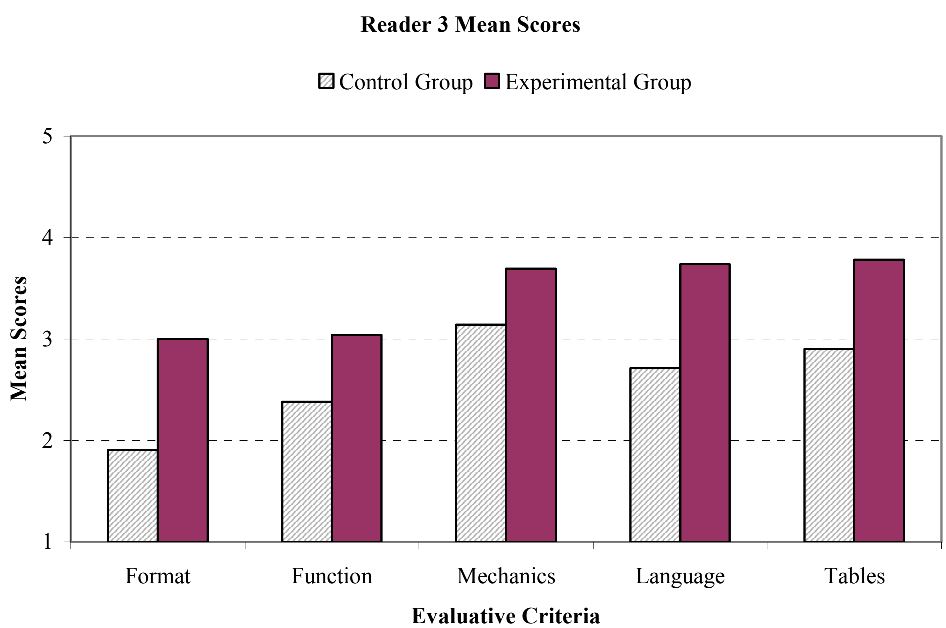


Fig. 3. Scoring of reports by Reader 3.

In terms of criteria evaluated, Reader 3 recorded the following: in criterion #1 (Format), an increase from control to experimental of 1.1; in criterion #2 (Function), an increase of 0.70; in criterion #3 (Mechanics), an increase of 0.50; in criterion #4 (Language), an increase of 1.0; and in criterion #5, (Tables and figures), an increase of 0.60.

Data for all improvements noted are summarized in Table 1 below.

Table 1: Mean Improvement within Criteria Scored, by Reader

| Reader | Format | Function | Mechanics | Language | Tables and Figures |
|---|---|---|---|---|---|
| 1 | 0.90 | 0.03 | -0.05 | 0.70 | 1.2 |
| 2 | 1.0 | 0.50 | 0.70 | 0.70 | 0.90 |
| 3 | 1.1 | 0.70 | 0.50 | 1.0 | 0.60 |

B. Standard Deviations

In terms of the variability within each reader's scores of the control sample, a preliminary analysis of standard deviations demonstrates, as per Table 2, below, that Readers 2 and 3 had less variability within their ratings than Reader 1.

Table 2: Standard deviations in control ratings by reader

| Reader | Format | Function | Mechanics | Language | Tables and Figures |
|---|---|---|---|---|---|
| 1 | 1.155 | 1.125 | 0.610 | 0.870 | 0.949 |
| 2 | 0.889 | 1.231 | 0.865 | 1.167 | 1.117 |
| 3 | 0.831 | 0.921 | 0.854 | 0.845 | 1.091 |

Table 3 shows the variability within each reader's scores of the experimental sample. Again, as with the standard deviations among the control sample, Reader 1 demonstrated the greatest spread.

Table 3: Standard deviations in experimental ratings by reader

| Reader | Format | Function | Mechanics | Language | Tables and Figures |
|---|---|---|---|---|---|
| 1 | 0.974 | 1.154 | 0.366 | 0.576 | 0.736 |
| 2 | 1.147 | 1.096 | 0.798 | 1.201 | 1.037 |
| 3 | 1.243 | 1.107 | 0.765 | 0.9638 | 0.902 |

C. Inter-reader Reliability

Consensus estimates of inter-reader reliability calculated by percent-agreement figures are shown in Table 4. These estimates show high levels of consensus.

Table 4: Consensus estimates of inter-reader reliability, calculated by percent-agreement figures

| Readers | Format | Function | Mechanics | Language | Tables and figures |
|---|---|---|---|---|---|
| 1,2 | 70.2 | 84.0 | 86.3 | 81.8 | 77.2 |
| 2,3 | 93.1 | 86.3 | 88.6 | 81.8 | 84.0 |
| 1,3 | 65.2 | 86.3 | 84.0 | 84.0 | 88.6 |

## Discussion and Conclusions

Based on our evaluation of the data received, we can see—with one exception, Reader 1's notation of a decrease in mechanics from control to experimental sample—a quantifiable improvement in readers' scores between the control sample and the experimental sample. The mean improvement was 0.78, with the strongest improvements being shown in Format (a mean of 1.0); Tables and figures (a mean of 0.90); and Language (a mean of 0.80). Mechanics and Function each improved by a mean score of 0.41.

Standard deviations in both control and experimental sample ratings of Readers 2 and 3 demonstrate far less variability than those of Reader 1, which may indicate a need for a stronger norming process: one reader, in effect, may be more internally inconsistent with scoring than the other two. And even though we see a high inter-reader reliability through our consensus estimates, we should note that these estimates entail a broadened definition of agreement between readers, as adjacent scoring categories are included. In sum, we have labeled "agreement" as any score that did not differ by more than one point above or below another score. If we were to calculate inter-reader reliability in terms of correlation coefficients, our scores would be lower. Again, this may point to the need for more intensive reader training.

With this and any writing assessment, certain variables that could possibly influence outcomes should also be noted: among them are students' innate writing ability and the quality of students' past writing instruction. Certainly student motivation is a mitigating element as well: we can provide students with the utmost in terms of support materials such as this and other style guides, but students are not always willing to put them to use.

Yet our preliminary findings demonstrate how our research question—"To what extent did the Style Guide impact the quality of finished lab reports?"—can be answered. As we might expect, there is a correlation between Style Guide use and the quality of format, tables and figures, and appropriate, professional language, or style. Conversely, the Style Guide appears to have had the least impact in terms of function (that is, clear, logical development of key ideas; unified paragraphs; and overall coherence) and mechanics, or grammar and punctuation.

Why might this be so? The authors submit that the Style Guide is an effective template, but a largely ineffective teacher. It is—and should be—easy for students to comprehend and implement the Style Guide's advice with regard to format (this is a matter of using the right heading in the appropriate place), language (the student can learn quickly to distinguish the imperative from the declarative, for example), and tables and figures (this is a matter of including strong, professionally-rendered examples for imitation).

The Style Guide, however, cannot teach composition and grammar, the two skills most needed to show stronger scores in both function and mechanics. The Style Guide cannot ask the student if in fact he or she has explained a foreign concept clearly and adequately, nor can it help the student with pronoun-antecedent agreement.

In the authors' view, the Style Guide cannot be considered a "stand-alone" means of automatically ensuring stronger lab report writing. The Style Guide needs to be taught, placed in a rich and ongoing context of deliberate writing instruction, through required coursework, seminars, writing center tutorials, or other writing-intensive initiatives.

Further research, in fact, can work to determine the role of writing-intensive instruction (including, among other means, the Style Guide) in the improvement of student writing. As we have noted above, the written proficiency of our students can never be assumed; it must be developed.

References

[1] Niiler, Lucas P. *General Education Writing Assessment Report*. University of Texas at Tyler Department of English, July 2002.

[2] Niiler, Lucas P. "The Numbers Speak : A Pre-Test of Writing Center Outcomes Using Statistical Analysis." *The Writing Lab Newsletter,* March 2003, 6-9.

[3] Wolcott, Willa, and Sue M. Legg. "Writing Assessment in the Disciplines." In *An Overview of Writing Assessment: Theory, Research, and Practice.* Urbana: National Council of Teachers of English, 1998. 143-159.

[4] Stemler, Steven E. "A Comparison of Consensus, Consistency, and Measurement Approaches to Estimating Interrater Reliability." *Practical Assessment, Research & Evaluation,* **9** (4). Retrieved March 1, 2004 from http://PAREonline.net/getvn.asp?v=9&n=4.

DAVID M. BEAMS
David Beams is an Associate Professor of Electrical Engineering at the University of Texas at Tyler. He received the B.S. degree in Electrical Engineering in 1974 and the M.S. degree in 1977, both from the University of Illinois at Urbana-Champaign. He was employed in industry for 16 years. He received the Ph.D. degree from the University of Wisconsin–Madison in 1997. He is a licensed PE in Wisconsin and Texas and holds or shares four patents.

LUCAS P. NIILER
Lucas Niiler is an Assistant Professor of English at the University of Texas at Tyler and directs The Writing Center, a campus-wide resource for improving the writing of students in all curricula.