Assessing and Improving Writing in the Engineering Curriculum*

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Two essential higher education outcomes, the ability to write effectively and the development of the reasoning skills necessary for effective writing, are both specifically addressed by ABET and highly sought by employers. Since writing is typically taught in courses outside the engineering college, students often lack the ability to write and reason effectively within the discipline. An innovative system is described to close the loop on writing improvement by comprehensively assessing writing effectiveness and providing a means of strengthening the weak areas.

Keywords: CLAQWA; cognitive skills; critical thinking; peer review; writing improvement

INTRODUCTION

THE IMPORTANCE OF WRITING in the engineering profession requires its continued development throughout the curriculum, and its specific development within the engineering discipline. Writing instruction therefore must not be, nor can it be, the sole responsibility of the English department in an institution. Although the institution as a whole should be involved, many faculty are not prepared to foster student writing in engineering. When the necessity of developing writing within the discipline is recognized, typically the English department is contacted. Students either go to the English department for courses or an instructor from English is sent to engineering departments. This external approach often is unsatisfactory.

The need to improve students' writing and writing instruction in engineering is well documented [1, 2]. The Accreditation Board for Engineering and Technology (ABET) requires as a program outcome the ability for students to communicate their ideas effectively [3]. To address writing improvement, the Cognitive Level and Quality of Writing Assessment (CLAQWA) was created and has grown into an assessment system capable of building a bridge across courses and closing the assessment loop. CLAQWA is unique because it has the ability to assess, in a single system, writing and thinking at the student, course, program and even institutional levels. More importantly, CLAQWA is designed to close the assessment loop by helping individual faculty, as well as programs, define writing expectations, assess student writing to determine if these expectations

have been met and provide substantive feedback for improving students' writing and thinking.

Over a period of approximately ten years, the CLAQWA system has evolved to include paper classroom and program assessment rubrics, a paper peer review feedback resource, as well as an online assessment, feedback, and tutorial system for students, instructors, programs, and institutions. In short, an assessment system has been created to identify and measure strengths and to measure and improve weaknesses.

A PROMISING SOLUTION

CLAQWA was conceived at the University of South Florida (USF) in response to needs identified in a two-year general education learning community program in which writing was taught across the curriculum. Because multiple instructors were involved in the creation of the writing assignments and the evaluation of students' papers, a structure was needed to evaluate writing consistently. Accordingly, CLAQWA, grounded in rhetorical principles (such as reasoning, organization and development, and quality of evidence), was designed to assist instructors and program evaluators with the assessment, diagnosis, and grading of student writing and thinking. Faculty teams representing a diversity of departments, programs and disciplines were involved with the development and validation of the original paper version of the instrument [4].

CLAQWA helps assess writing on two different scales: quality of writing and cognitive level attainment. Designed to be flexible to accommodate instructors' needs, each scale can be used separately or can be combined with others when appropriate. The scale for cognitive level assessment

assists with the development of the writing assignment and with the assessment of students' cognitive levels achieved in their writing. This scale is composed of four levels: (a) knowledge, (b) comprehension, (c) application and (d) analysis, synthesis and evaluation [5].

The quality of writing assessment scale consists of skills commonly found in writing texts [6–10], but is organized and clarified for any instructor who evaluates students' writing. Five scale points are described for each writing component organized into five primary writing categories:

1) Assignment Parameters;
2) Structural Integrity;
3) Reasoning and Focus Consistency;
4) Language, Contextual and Audience Appropriateness;
5) Grammar and Mechanics.

Each category is composed of multiple components. For example, in the 'Reasoning and Focus Consistency' category the five levels representing the range for each of the three elements, from excellent to inadequate, are described in Table 1.

Because CLAQWA is specifically designed for use in any discipline, it is very flexible and has broad applicability. Different components can be targeted for each assignment and skills can be weighted differently. Thus, the use of CLAQWA facilitates clear communication of the instructors' expectations and facilitates substantive feedback on students' writing and critical thinking skills, thereby enabling improvement.

In addition to electrical engineering, CLAQWA has been used in a variety of classes, such as English composition, technical writing, anthropology, computer engineering, first-year experience and chemistry. Several benefits have resulted from its use. First, instructors learn to assess writing consistently. Second, when instructors explain the writing skills contained in CLAQWA, and those identified for a particular assignment, students have a clearer understanding of the instructor's expectations and what constitutes quality writing. Third, because of the emphasis on thinking, students realize the importance of clear well-developed ideas that result from planning and revision. In short, writing improvement and clarification of ideas result. These improvements have been observed to carry over into other communication forms as well, including project proposals and presentations.

MORE EVIDENCE OF SUCCESS

CLAQWA also has been demonstrated to be effective for assessing programs. At USF, holistic and analytic scoring methods were systematically compared to determine the more effective approach for assessing writing at the programmatic level. The holistic method is the evaluation method typically used by the major testing agencies (ETS and ACT) for large scale assessment because of its efficiency and its success for achieving inter-rater reliability. This measurement criterion is of paramount importance for high stakes, large scale assessment, such as entrance exams and statewide accountability exams where a comparison to a particular group is desirable [11]. It has been criticized, however, for not providing students with feedback regarding their strengths and weaknesses [12].

Needing an efficient and consistent framework to evaluate students' writing, one that could help identify students' writing strengths and weaknesses, the CLAQWA analytic scale was introduced for program assessment. Studies were conducted to determine inter-rater reliability estimates for the CLAQWA scale, which revealed

Table 1. Example from CLAQWA Writing Scale

ORGANIZATION AND DEVELOPMENT: REASONING & FOCUS CONSISTENCY

Level	Reasoning
5	The text exhibits a logical progression of sophisticated ideas that support the focus of the paper.
4	The text exhibits a logical progression of ideas that support the focus of the paper.
3	The progression of ideas is interrupted by rare errors in logic, such as absolutes or contradictions.
2	The attempt at a progression of ideas is unsuccessful due to errors in logic, such as absolutes or contradictions.
1	The ideas are illogical and appear to reflect the writer's "free association."

Level	Quality of Details
5	Details develop the main idea and provide supporting statements, evidence, or examples necessary to explain or persuade effectively.
4	Details support the purpose and main idea of the text with adequate clarity, depth, and accuracy.
3	Details are related to the purpose and main idea of the text but do not provide sufficient clarity, depth or accuracy to explain or persuade effectively.
2	Details are loosely related to the purpose of the text but are lacking clarity, depth, or accuracy.
1	Details do not develop the purpose or main idea of the text.

Level	Quantity of Details
5	All points are supported by a sufficient number of details.
4	Most points are supported by a sufficient number of details.
3	Additional details are needed to develop **some** points.
2	Additional details are needed to develop **most** points.
1	Virtually no details are present.

substantial and respectable correlations (e.g. 0.80 and above). More importantly, the results from the CLAQWA instrument provided more valid results for improving writing and helping identify suitable curricular changes. In addition, after using CLAQWA for a number of years to assess student writing at USF, involving thousands of students' work, it became clear that students' performance on any given assignment is not best represented by a single score. A single score masks important variation in performance and thus leads faculty and students to miss an opportunity for improvement. With an analytic assessment approach however, the weaknesses and strengths uncovered in a course, section or program can be easily identified and subsequently targeted for improvement.

The paper version of CLAQWA has been used at USF for classroom and program assessment for approximately six years. Summative and formative program assessment purposes, as well as classroom instructional purposes can be addressed with this method. Because of CLAQWA's flexibility and applicability for multiple assessment purposes, instructors, graduate and undergraduate students and assessment teams from a wide range of disciplines find the instrument to be effective and have enthusiastically supported its use.

Assessment results and studies using CLAQWA revealed that multiple functions are served by using CLAQWA, such as:

- establishing criteria for specific assignments;
- communicating the writing and thinking skills expected for an assignment;
- providing guidance for consistently assessing papers;
- offering a framework with which to discuss papers' strengths and weaknesses, both for instructors and student, peers.

CLAQWA also is effective for assisting with program assessment, by:

- providing a mechanism for revealing change over time;
- identifying specific strengths or weaknesses in students' writing;
- assessing achievement of a specific writing skill level.

However, as the assessment progressed over time, additional needs were identified and have been addressed.

CLAQWA ONLINE AND PEER REVIEW

More recent discoveries led to additional developments to the CLAQWA assessment tool. Faculty expressed their lack of preparation to assess student writing and provide meaningful and appropriate feedback, and also requested a guide to writing revision and improvement. These needs led to the development of the online version of the instrument and a peer review process.

CLAQWA Online, initiated in 2005, is an adaptation of the paper and pencil assessment tool and includes a feedback/tutorial feature to help address weaknesses revealed in the results. After weaknesses in writing or thinking are identified through the online assessment system, students are able to view examples from different disciplines, including engineering, of the same weaknesses identified in their papers. Students then are able to view more proficient versions of the examples with detailed explanations as a guide to improve their own writing.

Systematic peer review of student writing also is being used at USF. A graduate student peer review team instructs students within classes to apply peer review protocols, based on CLAQWA, to different types of written work. The instruction session requires less than an hour of class time. In the peer review process, appropriate and meaningful feedback is encouraged, which then is used by the students to revise their writing. Instructors and students alike find the peer review process beneficial for producing writing that is well developed and contains better reasoning and quality of evidence. In short, better writing and thinking is fostered. Evidence has shown improvement in engineering students' writing after using the peer review process. Peer review also encourages engineering students to collaborate with other students, a mode that is often downplayed when requiring students to work independently. The spirit of collaboration has been observed to carry over into lab report writing, research activities and test preparation.

APPLICATION OF CLAQWA IN THE ENGINEERING CURRICULUM

The engineering curriculum presents many opportunities to demonstrate communication skills, both in the form of writing exercises and oral presentations. Most engineering courses have prospects for design activities. These design activities can culminate in a written presentation, an oral presentation, or both. Indeed, the design process should include a substantial communication component, according to the ABET definition of engineering design. Moreover, Wheeler, Balazs and McDonald advocate that engineering faculty demonstrate the importance of writing by incorporating more writing in their courses [13].

CLAQWA was first incorporated into electrical engineering courses at USF in Spring, 2005, when it was used to evaluate writing samples from an engineering professional issues course. A sample of 25 essays was evaluated using the CLAQWA system, both before and after peer review. Table 2 compares the mean scores for five of the 16 elements evaluated, along with the percent scoring

Table 2. CLAQWA / Peer review results

Element	Before Peer Review			After Peer Review		
	Mean	≥3.5	<2.5	Mean	≥3.5	<2.5
Appropriate Audience	3.00	12%	8%	3.14	36%	4%
Opening supports main idea	2.90	8%	12%	2.98	8%	4%
Reasoning supports main idea	2.78	12%	20%	2.79	8%	12%
Accurate word choice	2.79	12%	20%	2.93	8%	8%
Consistent viewpoint	3.09	24%	16%	3.16	36%	16%

3.5 and above (desired level) and the percent scoring below 2.5 (unacceptable level).

Although these data do not constitute a comprehensive analysis of the effectiveness of applying CLAQWA and peer review in the engineering curriculum, they are typical and do show an encouraging trend. With just one exposure to the CLAQWA system and the peer review process, significant improvements can be detected in many students.

When CLAQWA was applied in the engineering curriculum at USF, problems in the form of lower than desired scores were detected. The solution to these problems was found to be a combination of peer review and formal feedback provided to the students by the CLAQWA instrument. These solutions help close the loop, as evidenced by higher scores.

The use of the CLAQWA system also encouraged a change in pedagogy. More emphasis was placed on the importance of effective writing in the engineering environment. Specific cases including proposal writing, procedure documentation, and design descriptions were analyzed using the peer review protocols learned as part of the CLAQWA system. This exercise reinforces the importance of effective writing.

The use of CLAQWA and peer review in the engineering curriculum will be expanded over the next year at USF. In addition, specific weaknesses identified from the CLAQWA results, such as reasoning, will be addressed. The authors are confident that the trends of improvement observed thus far will continue.

CONCLUSIONS

Application of an assessment tool, able to determine both cognitive level and writing quality, is an important step in improving communication skills. CLAQWA provides this assessment ability as well as a means to provide individual feedback to strengthen the detected areas of weakness. When combined with peer review, CLAQWA has demonstrated improvement in writing samples from the electrical engineering curriculum at USF. These improvements were evident upon the first use of the system. The critical review and peer feedback concepts learned in the CLAQWA training also were observed in other areas, suggesting that the students recognize the value of these concepts and voluntarily apply them throughout their engineering courses.

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