The Right Answer Is Communication When Capstone Engineering Courses Drive The Questions

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ABSTRACT

New graduates striving to become successful engineers must use communication to interact with superiors and colleagues. This paper reports the results of a four-year development program using the capstone design course as a driver for developing engineers' communication skills. Faculty assessment of the program, as well as post-graduation feedback from the program's graduates, is included. Significant benefits from this approach include preparing students to enter a communication-based engineering workplace through a just-in-time learning experience that enhances students' buy-in to the material. Programmatic advantages include having a curriculum that supports ABET (Accreditation Board for Engineering and Technology) 2000 ideals.

I. Introduction

"We're going to learn one word this year and that word is communication. The right answer to nearly all questions in this course is communication."

Over the past four years, these words, spoken on day one of New Mexico Tech's senior design course in Electrical Engineering, have caused students to stop and wonder if they were sitting in the right classroom. After all, the senior design course is a capstone experience often used to test the abilities students have developed in their previous years of technical classes. Engineering students tend to hold onto the myth that technical communication is not going to be a major component of their future lives. They also tend to believe that the constant bevy of lab and project reports they are required to write as part of their academic program is not representative of their post graduation experience. Yet, as previous research indicates, "simply amassing data is not sufficient; rather, today's professionals must be able to interpret and repackage the data for audiences" [1, p. 152].

In larger engineering projects, both in government and private sectors, there has been a strong move towards creating multidisciplinary teams for major project development. This shift towards multidisciplinary work mirrors trends across all disciplines. The requirement for scientists, engineers, and other professionals to work together demands useable documents and presentations that can be understood by audiences with different levels of knowledge. Communicating quality engineering cannot fall onto professional writers alone, but rather engineers must shoulder the burden of being able to present their ideas.

The reporting structure in many dynamic companies requires that an engineer no longer just speak to other engineers, but rather to a whole range of individuals in the corporate structure. In many situations engineers are addressing financial managers, strategic planners, or others who will not be swayed by the compelling nature of the engineering involved in the project, but rather by how well the project fits within the company's world view. As Swarts and Odell argue, "…writing in engineering is not simply talking about data and facts and letting the facts 'speak for themselves." Engineers must be "advocates for those data" [2, p.6].

In response to these realities, the question facing most engineering professors teaching capstone design courses is "How do we get students to 'buy-in' to the importance of communication, both in a team-based course and within the future team-based environments they face?" In addition, "How do we incorporate ABET's (Accreditation Board for Engineering and Technology) communication focus into the capstone design course?" In this article the above questions are addressed through presenting the benefits of a unique multidisciplinary approach to the engineering senior design course, one that emphasizes communication. The article begins by reviewing recent studies in the area of engineering communication. Following a review of related literature, a model is presented for the communication-based capstone design course by providing background information about the Electrical Engineering senior design course at New Mexico Tech and describing the role technical communication plays in this course. Then detailed observations regarding students' approaches to design presentations are shared, and implemented changes based on these observations are discussed. Feedback from former students is included. The article concludes with benefits for both students and faculty.

II. Previous Research On Communication Within Engineering Education

As engineering students move into the workplace, their success is as dependent on their ability to communicate as it is on their technical skills. According to studies of professionals in the workplace [3,4], engineers may spend up to half of their time writing, with the amount of time spent writing correlated with position within an organization. Other studies [5-

7] suggest that oral and written communication skills play a pivotal role in determining the workplace success of new graduates.

In response to this need ABET has defined communication competence as one of the objectives for engineering curricula. Accordingly, many programs have begun implementing curricular changes, and these changes and innovations have been reported in the literature.

At the end of the twentieth century and beginning of the twenty-first century, as universities were becoming familiar with ABET 2000 criterion and its emphasis on "effective communication", many educators began reporting the techniques they used in their classrooms to integrate writing instruction in engineering curricula. Several articles from this period discuss curricular techniques. For a more extensive review of articles pertaining to engineering communication curricula, courses, and support systems see Ford and Riley (2003) [8].

Other studies report results of assessing writing within the engineering discipline, such as an investigation of knowledge transfer of writing instruction [9], comparisons between writing and engineering instructors' standards for writing [10], and a study asking whether or not engineering students improved communication skills after completing writing assignments in engineering classes [11].

Fewer studies focus specifically on the capstone design course. Researchers using capstone design courses as sites for study have examined problem-based education [12, 13], student collaboration and social interaction [14-18], and a range of professional practices [19-22] more so than oral and written communication practices in the capstone design course.

Works that do focus specifically on written and oral communication within the capstone design course include a reported interdisciplinary effort in engineering design and communication developed to help students recognize the connection between writing and engineering tasks [23]. Norback et al. (2002) present a "set of criteria of communication excellence" obtained from industry interviews and model documents and suggest strategies for including this criterion within the senior design course [24], and Brinkman and van der Geest (2003) share methods for assessing communication competencies within engineering design courses [25]. Dannels' (2003) study investigates the contradictions within the teaching and learning of design presentations in three mechanical engineering design courses [26].

Even with these studies, there are, as Dym et al. (2005) state, "a number of open research questions associated with teaching design thinking and with effectively implementing project-based design education" [12, p. 112]. This article addresses the previously-stated questions concerning how to teach engineering students communication skills alongside of technical skills. Rather than a communication approach that focuses on grammar, mechanics, and punctuation, the approach advanced in this article teaches students "critical thinking and audience analysis" concepts that Williams (2002) notes as underlying "truly effective engineering communication" [27, p. 202]. Findings and implemented changes from a four-year effort concerned with developing a communication-based capstone design course are presented.

III. Background

In recent years ABET has begun to look for more outcomes from engineering programs, including abilities to work on multidisciplinary teams and present work orally and in writing. One of the focal points for the Electrical Engineering program at New Mexico Tech has been to meet these ABET requirements by combining aspects of the technical program with communication. The goal of the department is to produce graduates who are well prepared to enter public or private sector positions or graduate school.

A. The Evolution of the EE Capstone Design Course at New Mexico Tech

The Electrical Engineering program at New Mexico Tech was started in 1989, ABET accredited in 1992, and continues to be ABET accredited. Initially, the capstone design program was mainly project centric, focused on the technical applications of engineering and design. As the program evolved, the design component was formalized into the classroom and took on a strong design centric format, in keeping with the aims of ABET. The next step in the development of the capstone program, now in place for the past four years, involved strengthening the program's communication aspects by introducing structured writing assignments, including a final thesis and a unique set of presentations. Initially the value of this approach was questioned, both by students and faculty, yet the choice of a communication-based course dovetailed directly into ABET

2000 which focuses on communication, multidisciplinary work, and preparing students to transition from school to work.

As it evolved, the benefits of a communication-based capstone program became apparent and anecdotal evidence began illustrating the improved performance of the students in public speaking, teamwork, and in transitioning into their first employment positions. This positive reinforcement encouraged incorporation of greater structure, particularly in regards to communication-based tasks, within the program. Over the past four years, the Electrical Engineering capstone program at New Mexico Tech has developed an emphasis on providing students with an understanding of the role of communication, team dynamics, and project management while maintaining significant technical challenges through real-world projects sponsored and provided by government labs and the private sector.

B. EE Capstone Design Model

The year-long course requires students to work in teams to prepare, design, develop, deliver, and present a project to a number of external reviewers including the project client, other faculty, and senior engineers. Students must draw on their technical expertise as well as rely on, or develop new, skills in written and oral communication, organization, and teamwork to successfully complete a project.

At the start of the program 15-25 projects are submitted from various organizations in industry, the Department of Defense, and faculty members for the students to review and rank based on their interest. The class is divided into teams of 4-6 members, a number suggested by previous research [28]. Student teams are assigned based on their individual interests in working on a specific project and additional selection criteria to minimize the number of team members who may have worked together previously in their introductory design course.

Each team works with a faculty mentor and a project sponsor (customer) and often has considerable flexibility in realizing the final design. Each team must evaluate the technical issues surrounding their projects and develop a project Statement of Work that covers the period of the academic year. The Statement of Work includes time management, budgeting, resource management, a description of the project, and required tasks to be solved. The students must remain within their budgets and may only deviate from their Statement of Work deliverables in consultation and agreement with the project sponsor.

In addition to the Statement of Work, teams develop a number of other written documents including formal reports, status reports, technical reports, a final presentation and a final thesis. Additional documents such as user manuals are often required by the project sponsors. Teams must produce these documents as well as plan and deliver oral presentations.

The program is taught with a unique approach that uses a "just-in-time" or a "timely reintroduction of concepts" methodology to reinforce the needs of both engineering design and communication. In the early stages of the course, many of the required concepts, such as system reliability, integrating the scientific method and effective communication strategies, are introduced to the student teams, but these remain as abstract concepts that they cannot yet apply.

The "just-in-time" approach evolved from observing that early in the lifespan of the project most of the student teams were not ready to devote attention to the subtleties of these concepts. To improve student retention of these ideas and the ability to apply them they are reintroduced with a deeper technical focus at a time when the majority of the teams have reached the point where these issues are arising. This 'just-in-time" approach to delivering the information finds the students ready to receive this information and provides students an actual context in which to understand these concepts. This approach is particularly advantageous when introducing students to the concepts surrounding case studies on ethics or when considering contemporary issues as they relate to design decisions. In this context-based situation, the students are more receptive to using and applying these concepts and they become demonstrated within the student work, thus reinforcing several ABET outcomes. Applying these concepts in conjunction with the technical aspects of their projects and reporting the results of these efforts in their final presentation and thesis helps to reinforce these concepts. The detailed educational approach and rubric that is being used in the program will be reported in more detail in a future article.

C. Capstone Design Presentation Sequence as an Assessment Tool

As Driskill (2000) notes, "assessment related to [ABET] criterion 3(g) must weigh whether a student is ready to communicate effectively in industry and professional settings" [29]. One of the key ways in which the Electrical Engineering

program at New Mexico Tech assesses effective communication is through the senior design presentation sequence, where "real" audiences play an integral role.

Conceptual, Preliminary, and Critical Design Reviews are used to provide feedback to the students on their progress. At each design review, reviewers include the course professor, at least two other Electrical Engineering faculty, and Technical Communication faculty. Industry professionals and former senior design students serve as reviewers as well. The student teams are evaluated by reviewers on the following areas: introduction, background, design, planning, and overall presentation quality. Reviewers provide both quantitative and qualitative evaluation of the student's performance.

Technical Communication faculty provide extensive comments to the course professor regarding each team's communication strengths and weaknesses. While the comments of the other reviewers are based on design issues and the actual engineering represented in the presentations, technical communication reviewers focus on communication competencies.

Following each of these presentations, Electrical Engineering and Technical Communication faculty meet to discuss observations and evaluations for each team. The benefits of this level of interaction between the two faculties cannot be overstated. As an example, when students are presenting to other engineers, many of whom have knowledge of the area, they can easily appear as providing the right information in the right fashion. In reality, to other audience members, engineer or not, those same students are often not communicating at all. As reviewers, Technical Communication faculty focus on the delivery of information by the students and are in a strong position to bring those observations forward. In follow-up discussions, the combined expertise of the faculty members allows the engineering concepts to be combined with technical communication to evaluate the students and to diagnose areas in the students' program needing improvement.

The experience of presenting and receiving feedback for these three design reviews sets the foundation for students for their final presentations. The final presentations take place at the end of the Spring semester in a formal setting, with audience members including other engineering students, faculty, clients, and members of the Electrical Engineering Department's Advisory Board, comprising engineers from government facilities and the private sector.

IV. Assessment of Student Performances Over The Last Four Years

Over the last four years, students' performances during the design reviews and behaviors in the classroom demonstrate that they have challenges presenting a big-picture view of their projects. Often the teams get lost in thinking and talking about the technical specifications and have difficulty appropriating material for their audience. This trend may be underpinned by several factors:

- Difficulty understanding client's expectations. Clients present student teams with a problem to solve, but often this problem is not packaged neatly. Many students lack experience working on the complexities of real-world projects. This complication is often experienced by students working on client-based projects [16].
- Failure to interact regularly with the team client and faculty sponsor. Teams who are struggling with the client's specifications may avoid contact with their sponsor out of fear of appearing unknowledgeable or not knowing the answer. However, contact with the client and faculty sponsor is often what students need to receive project clarification.
- Difficulty applying engineering concepts to solve problem. Students are much more comfortable working independently and using trial and error approaches to solving technical issues. For student engineers, using design studies and simulations are not practiced approaches. In addition, it is a challenge for students to develop multiple solutions to explore; instead they tend to cling tightly to one solution, even after it is demonstrated not to work.
- Failure to consider audience and their interests in project. Even though the majority of the capstone design students take a required technical communication course which stresses the concept of audience (survey results at the beginning of the 2004-2005 academic year indicated that 23 out of 25 students had taken a required technical communication course), in their early presentations students make few or no attempts to accommodate their content towards the needs of their audience. Both the selection of content and the organization of it tend to be problematic. In particular, students show:

- Difficulty selecting content and paring down information to fit within a 15 minute presentation. Students encounter problems determining what is necessary to include in presentations and what to omit. Students also have trouble condensing details. In their preliminary and conceptual design reviews students often get lost in the technical particulars.
- Difficulty establishing a context at the beginning of presentation to which the audience can understand and relate. Initial presentations (preliminary and conceptual design reviews) show weak or no attempts to introduce the audience to the project and its purpose/usefulness. Later presentations shows more effort (per instructor's requirement), but the information is still rushed through. Most of the teams fail to speak in terms a general user could understand, and very few of them use examples to explain the significance of project.
- Difficulty organizing the presentation's components. While they are told by their professor what parts to include in the presentation, the students experience challenges figuring out the logical order of those parts.

To help remedy the aforementioned problems student design teams encounter, a number of strategies have been included in the design course curriculum. These strategies, a few of which are described following, help to reinforce the concept of shaping oral and written material appropriately for one's audience.

The first difficulty faced by the students after they have been teamed up and have begun to prepare their Statement of Work is to understand at a functional level what the project is about. This problem is one of the most difficult ones faced in the program as the students are very comfortable just repeating their customer's instructions. Typically, they fail to investigate the project sufficiently to really understand what they are being asked to do.

Each team is required to select a point of contact who will communicate with the course professor and project sponsors and a team leader, the individual on the team responsible for communication within the group. The remainder of team members are the "other engineers" who will take on duties such as taking a technical lead on a particular subproject. To force the team to develop an understanding of the project, several classroom exercises are performed over several weeks. The most successful exercise has been to have one of the team members at the board being asked to write down their project's "one line description" of the project. This technique, which is used often within technical communication and composition classes to help students state their thesis, is part of a planning or budgeting exercise. The one line description is then discussed by all members of the class, ever refining the description. The result is that the students distill out a description of their project that is clear, jargon-free, and understandable by non specialists. Through this exercise students refine their vision of the project.

The exercise is repeated so that all members of the team are put in a position of having to describe the project in one line. As a result, after it has happened a few times, the team members get together independently outside of class and put together a much better description of the project.

The pop presentations, the term 'pop presentation' being a play on the idea of a 'pop quiz', are the next evolution of honing the students' presentation skills. The students are informed of the need to have an up-to-date presentation available at any moment, with visual aids. The scenario presented to the students is that on an average day at the office, their manager stops in and informs them that they have just been granted five minutes of the engineering director's time to present their project. The concern is that the company is looking to cancel some projects and as a result they need to justify their project and its status. In particular they will need to describe the major technical issue they are presently facing.

In the second half of the program the pop presentations can happen in any class with little or no notice. This means student groups not only have to be ready to present, but that each member of the group be present to support the team. Typically, three pop presentations are made by each team.

Through the progression of planning a fifteen minute presentation to summarizing a project in one sentence to delivering a project summary in five minutes through in-class pop presentations, students begin to apply effective technical communication skills. In particular, through this process students learn how to think beyond their project teams and consider an outside audience, think carefully about the needs of this outside audience, and accordingly, shape content for this audience.

V. Assessing The Benefits

Capstone programs provide students with an opportunity to learn and try out their project management, engineering, and technical communication skills in an educational environment. Thus on graduation they have effectively seen what a "real world" project looks like. In particular, they have the opportunity to experience what expectations others may have in them. In this environment, they can make mistakes and yet not face the same impact of being on the job.

Anecdotal evidence shows that while many students do not see the value of the capstone program with a focus on project management and communication prior to their graduation, these students do realize the value of the capstone course later. Faculty have received e-mails from past students commenting on how much better and faster they are able to adapt and progress to the communication-centered workplaces in which they now work.

Some examples of comments from past students are:

> *"My project has come full circle and we are nearing our conceptual design review, and lo'n'behold, I have to give a 40 minute presentation all by my lonesome! I was just making a few slides about the various aspects of my subsystem and it made me think of doing the same thing more than a year ago for senior design. … Go figure, all one has to do to keep their job is do the work, do it right, and do it under budget. If I had known that in school, it would've been a lot more fun. Wait, I did know that."* Senior Design Student from 2003-4.

> *"Because of my experience in the course, I am now leading two projects only a year after [Senior Design]. The relentless and oftentimes unannounced presentations and papers prepared me for the papers and presentations I have to give regularly in my job. … I feel that because of the [Senior Design] course, I am ahead of the curve."* Senior Design Student from 2002-3.

> *"[Since completing Senior Design] I have given a number of talks, seminars and written publications on the work that I have been doing. Seeing some of these "real-world scenarios" before entering the scientific community was very beneficial."* Senior Design Student 2002-3.

As these comments illustrate, the communication-based capstone course provides multiple benefits for students. From this multidisciplinary endeavor, students' successful completion of the capstone course has allowed them to gain experience:

- presenting to audiences beyond the classroom
- framing engineering problems in ways non-engineers can understand
- using communication to solve "real-world" technical problems
- working on a team
- learning project design, with a model to refer to in the future

Through these experiences students become sensitive to the communication-based engineering world they will soon be entering.

There are also significant benefits to the professors involved in the capstone courses. From this multidisciplinary endeavor, Technical Communication faculty receive opportunities to:

- Better understand communication expectations in another department
- Better understand approaches/responses to communication assignments in engineering discipline
- Bring information about engineering communication back to their own technical writing classrooms (which are filled with several engineering students)
- Adopt educational strategies used in the capstone course for technical communication classes (such as the pop presentations)

From this multidisciplinary endeavor, engineering faculty receive opportunities to:

- See students through another set of eyes with different criteria for evaluation
- Establish a connection to experts in technical communication to evaluate techniques or obtain new ones
- Influence Technical Communication faculty with expectations of engineering managers
- Present students a vision of themselves as seen by other communicators

These benefits underline the importance of continuing multidisciplinary senior design efforts. However, this curricular technique begs further research. Continuing studies could include analyzing patterns of communication weaknesses within written assignments, assessing the transfer of skills from technical communication courses, evaluating student approaches towards collaborative communication assignments, and investigating the impact of capstone programs in graduate work.

VI. Conclusion

These observations help to identify and support the advantages of a cross-curricular approach to the capstone design course. While the communication-based curriculum requires a shared commitment from engineering and humanities faculty, the benefits this multidisciplinary experience can provide for students are worth the extra time and energy.

The significant benefits from this approach include producing students who are better prepared to enter a communication-based engineering workplace, have bought into this concept through a just-in-time learning process, and have demonstrated design experiences. Programmatic advantages include having a curriculum that is aligned with and supportive of ABET 2000 ideals.

Students taking the capstone design course may initially question the emphasis on communication and be unable to fully realize just how important written and oral communication skills are at various points during the course. However, upon leaving the classroom and entering professional engineering environments there is no doubt that these new engineers will be required to present their ideas orally and in writing. When the time comes when they are asked to put together an impromptu presentation or prepare for a critical design review, these students can refer back to their experiences of having completed these tasks in the classroom. And hopefully, at that moment they will understand that communication plays a crucial role in engineering design, that communication is what helps them get their ideas supported, that communication is the answer.

References

1. Bonk, R.J., P.T. Imhoff, and A. H.D. Cheng. "Integrating Written Communication within Engineering Curricula," Journal of Professional Issues in Engineering Education and Practice, 128.4 (2002): 152-159.
2. Swarts, J., and L. Odell. "Rethinking the Evaluation of Writing in Engineering Courses." ASEE/IEEE Frontiers in Education Conference Proceedings, October 2001, 1-6.
3. Silyn-Roberts, H. "Using Engineers' Characteristics to Improve Report Writing Instruction." Journal of Professional Issues in Engineering Education and Practice 124.1 (January 1998): 12-16.
4. Paradis, J., D. Dobrin, and R. Miller. "Writing at Exxon ITD: Notes on the Writing Environment of an R&D Organization." Writing in Nonacademic Settings. Eds. Lee Odell and Dixie Goswami. New York: Guilford Press, 1985: 281-307.
5. Kreth, M. L. "A Survey of the Co-op Writing Experiences of Recent Engineering Graduates." IEEE Transactions on Professional Communication, 43.2 (June 2000): 137-151.
6. Lang, J.D., et al., "Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers," Journal of Engineering Education, 88. 1 (1999): 43-51.
7. Vest, D., M. Long, and T. Anderson. "Electrical Engineers' Perceptions of Communication Training and Their Recommendations for Curricular Change: Results of a National Survey." IEEE Transactions on Professional Communication 39.1 (March 1996): 38-42.
8. Ford, J. D., and L. A. Riley. "Integrating Communication and Engineering Education: A Look at Curricula, Courses, and Support Systems." Journal of Engineering Education 92.4 (2003): 325-328.
9. Ford, J.D. "Knowledge Transfer Across Disciplines: Tracking Rhetorical Strategies from a Technical Communication Classroom to an Engineering Classroom," IEEE Transactions on Professional Communication, 47.4 (2004): 301-315.
10. Smith, S. "What is "Good" Technical Communication? A Comparison of the Standards of Writing and Engineering Instructors." Technical Communication Quarterly 12.1 (2003): 7-24.
11. Gruber, S. D. Larson, D. Scott, and M. Neville. "Writing4Practice in Engineering Courses: Implementation and Assessment Approaches," Technical Communication Quarterly 8.4 (Fall 1999): 419-440.
12. Dym, C.L., et al. "Engineering Design Thinking, Teaching, and Learning," Journal of Engineerng Education, 94.1 (2005): 103-120.
13. Denayer, I., K. Thaels, J. Vander Sloten, and R. Gobin. "Teaching a Structured Approach to the Design Process for Undergraduate Engineering Students by Problem-Based Education." European Journal of Engineering Education, 28.2 (2003): 203-214.
14. Norman, Rose, and R.A. Frederick. "Integrating Technical Editing Students into a

Multidisciplinary Design Project." Technical Communication Quarterly 9.2 (2000): 163-189.

15. Wojahn, P., et al. "Blurring Boundaries between Technical Communication and Engineering: Challenges of a Multidisciplinary Engineering Project." Technical Communication Quarterly 10.2 (2001): 129-148.
16. Dyke, J., and P. Wojahn. " Getting Dissed: Technical Communicators in Multidisciplinary Engineering Teams," Proceedings, 2000 IEEE Transactions on Professional Communication, IEEE 2000, 7-23.
17. Reid, F.J.M., S. Reed, and J. Edworthy. "Design Visualization and Collaborative Interaction in Undergraduate Engineering Teams," International Journal of Cognitive Ergonomics, 3.3 (1999): 235-259.
18. Miller, R. L., and B. M. Olds. "A Model Curriculum for a Capstone Course in Multidisciplinary Engineering Design." Journal of Engineering Education 83.4 (1994): 311-316.
19. Hanna, A.S. and K.T. Sullivan. "Bridging the Gap between Academics and Practice: A Capstone Design Experience," Journal of Professional Issues in Engineering Education and Practice, 131.1 (2005): 59-62.
20. Butkus, M.A., and M.B. Kelley. "Approach for Integrating Professional Practice Issues into Undergraduate Environmental Engineering Design Projects," Journal of Professional Issues in Engineering Education and Practice, 130. 3 (2004): 166-172.
21. Jenkins, S.R., et al., "Capstone Course in an Integrated Engineering Curriculum," Journal of Professional Issues in Engineering Education and Practice, 128. 2 (2002): 75-82.

22 Smith, R.P., and A. Leong. "An Observational Study of Design Team Process: A Comparison of Student and Professional Engineers." Transactions of the ASME, Vol. 120, December 1998, 636-642.

23. Schwom, B., and P. Hirsch. "Re-envisioning the Writing Requirement: An Interdisciplinary Approach." Business Communication Quarterly 62.1 (1999): 104-107.
24. Norback, J.S., G. A. Forehand, S.A. Jernigan, and A.B. Quinn. "Teaching Workplace Communication in Senior Design." ASEE Annual Conference Proceedings, 2002.
25. Brinkman, G. and T.M. van der Geest. "Assessment of Communication Competencies in Engineering Design Projects," Technical Communication Quarterly 12.1 (2003): 67-81.
26. Dannels, D.P. "Teaching and Learning Design Presentations in Engineering." Journal of Business and Technical Communication, vol. 17, no.2, April 2003, 139-169.
27. Williams, J.M. "The Engineering Portfolio: Communication, Reflection, and Student Learning Outcomes Assessment," Int. J. Engng Ed. vol. 18, no. 2, (2002): 199-207.
28. Griffin, P.M., Griffin, S.O., and D.C. Llewellyn, "The Impact of Group Size and Project Duration on Capstone Design," Journal of Engineering Education, 93.3 (2004): 158-193.
29. Driskill, L. "Linking Industry Best Practices and EC3(g) Assessment in Engineering Communication." 2000 ASEE Annual Conference, ASEE, 2000.

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