Writing to Design/Designing to Write: Using the Correlations between Communication and Engineering to Improve Student Reflection

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Abstract

Currently engineering programs in the U.S. are incorporating design into technical curricula, from first-year design experiences to senior capstone, client-centered projects. Included in the engineering design emphasis is a focus on inter-personal skills that enhance professional engineering work, particularly communication. The purpose of assigning students to a capstone design project is to give them the opportunity to develop their skills in the context of a situated learning experience. As such, we expect students to achieve a specific set of learning outcomes that are not customarily required in the traditional engineering classroom. This paper identifies learning outcomes in both design and writing, then associates strategies from each field as methods to improve student learning. Borrowing strategies across disciplinary boundaries, this paper provides valuable insights for faculty in both engineering and technical communication who are interested in expanding the repertoire of strategies they use to teach design and communication.

Introduction

Engineering design and writing, especially technical writing, are processes that are receiving increased attention within engineering curricula. Both engineering design courses and technical writing courses instruct students in processes that create artifacts with a purpose: a document that works, a design that works. In addition to a common purpose, writing and engineering design are often closely related in engineering practice. Technical writing is often aimed at creating documents—e.g., memos, reports, or manuals—that are closely tied to an artifact or the process of creating an artifact. Engineers who are creating an artifact, in addition to creating the artifact, often generate numerous documents about the artifact. Therefore, practicing engineers commonly couple the two synthetic activities.

Although the processes of technical writing and engineering design are closely related in practice, students often learn about the two processes in unrelated courses. Engineering students learn about design via a class in their engineering program; engineering students often leave the department to attend a technical writing course offered by a different program. There are, of course, exceptions to this general rule. Recently, capstone engineering design courses are more often coupled with technical writing courses. Professors from New Mexico State University (Wojahn, Dyke, Riley, Hensel, and Brown) have shared their experiences with developing a capstone, client-based course that teamed engineering students with advanced students in technical writing.[1] Also, there are examples (University of Michigan, Arizona State University, University of Wisconsin) where first-year engineering design courses are coupled with first-year composition courses.[2] Gruber, Larson, Scott, and Neville describe the interrelations of writing and design at the sophomore level in a two-semester engineering design course at Northern Arizona University.[3] The trend toward blending design instruction with writing instruction demonstrates that students benefit from such combined pedagogical efforts.

If there is a gap between technical writing and engineering design in the experiences of students, the gulf between faculty members who teach either engineering design and technical writing appears to be larger. The literature in technical writing does not appear to reference work in engineering design and vice-versa. The purpose of this paper is to explore strategies that might carry across the fields of engineering design and technical writing, with the twin goals of improving communication between faculty members in the two fields and providing learning activities that can improve the experiences of students.

Cognitive Processes in Writing and Design

Traditionally, faculty teach both design and writing by requiring that students create artifacts and then providing feedback to students about the quality of the artifacts. In design courses, students may work on one project for an entire semester. In technical writing courses, the focus of the course may be one large technical report due at the end of the semester. In both cases, the focus of the course is often on the quality of the final product instead of the improving capabilities of students either to write or design. However, faculty members in both courses frequently state the goal of the class is to improve the proficiency of the students with respect to either the writing or design process. To become more proficient at either writing or design, students need to improve a collection of processes through which they either design or write, instead of concentrating on producing a high quality final product.

Perhaps the best analogy we have for the cognitive processes involved is from music. Pianists, learning to play a new work, do not play the entire piece from beginning to end repeatedly with the intention to raise the quality each time. Instead, they select small sections of the piece that require very different techniques and practice those sections repeatedly to master the technique required for each section. Further, they may not play the section repeatedly without variation. Instead, they may purposely practice variations of the section that are different from the music that is written but that help to refine the desired technique.[4-6] By analogy, writers improve more by practicing to improve specific cognitive processes, rather than drafting and revising a single artifact. Similarly, emerging engineers would improve their ability to design by practicing to improve specific cognitive processes required for design, rather than working for an extended period of time on a single design. So facilitating learning shifts the focus away from practice on particular performances to practice on the techniques and cognitive processes required for the designated area of performance, whether music, writing or design.

Practicing on specific sections in ways that improve specific techniques or specific cognitive processes might be inferred to be "dedicated practice." Ericsson has defined dedicated practice as "a well-defined task with an appropriate difficulty level for the particular individual, informative feedback, and opportunities for repetition and corrections of errors."[7] Further, Ericsson indicates that the development of expertise is correlated with time spent in "dedicated practice," instead of just time devoted to practice. To help engineers improve their ability to write or design, it seems reasonable to craft activities that offer dedicated practice for these skills. Furthermore, if students can gain such practice in multiple situations, in both technical communication class and in design class, then we have provided them with additional opportunities to enhance their skills.

Engineering design is frequently taught as a sequence of stages. Although researchers have proposed many different models of design, they all tend to focus on sequential stages with iteration. That is, a designer would work on the first stage, e.g., defining the problem, then would work on the second stage, e.g., generating alternative solutions, and so on. Models of the design process do include opportunities to return to earlier stages and modify the results constructed during that stage, but the sequential nature of the model remains. Using these models as a starting point for teaching design, a teacher would provide students with an overall description of the engineering design process and help students improve their abilities for each stage in the process. Research by Atman, et. al., however, has shown that students working on design problems tend to move back and forth between stages in the design process.[8-10] They don't work on the stages sequentially. Thus, the research might suggest that a model of engineering design as a set of concurrent processes, as opposed to a sequence of stages, might be more appropriate for teaching design.

Even as we argue for the correlations between the teaching of design and the teaching of writing, we hope to move away from a preoccupation with the "stages" associated with both processes. In fact, writing instruction has historically been conceptualized as a process as well, although recursive in nature.[11] We find as writing teachers, however, that even when we emphasize writing's non-linearity, students customarily fall back into the "stages of the process" model, looking upon revision as an annoying impediment to the true goal: finishing the final document in the shortest time possible. Further, they tend to feel resentment at "returning" to any "earlier" stage of the writing process. One challenge presented to teachers of both writing and engineering design is how best to offer students a model for considering their work in terms of concurrent processes rather than linear stages. If we can do so, we can give students dedicated practice in the conceptual skills necessary to produce successful artifacts in realistic situations.

Achieving Learning Outcomes through Design and Writing Strategies

The purpose of a senior capstone design course is to provide students a situated learning experience that is relevant to their future professions as engineers.[12] Building on the technical courses students take in their engineering curricula, the capstone design course represents the application of a variety of technical skills to an open-ended problem, a situation that mimics the real-world work of professional engineers. Unfortunately, the tasks presented by a design project cannot be solved with technical abilities alone; rather, students must rely on an array of technical and non-technical skills in order both to create a successful design and to negotiate the numerous inter-personal challenges that permeate the work. In addition, it is our contention that looking upon the technical and non-technical challenges of the design project as distinct represents a profound misunderstanding of how an engineering team actually accomplishes its work.

Given that design and writing are so intertwined in the design process, we find that engineering faculty may look toward both fields for strategies to help students achieve particular learning outcomes and enhance their reflection on their own learning. We have identified these outcomes as the following:

- Developing effective relations with the client that facilitate design
- Recognizing the value of team work
- Alternative generation
- Usability testing

These outcomes represent only four of the many outcomes faculty may envision as part of a design course. We find, however, that the outcomes listed above bring design and writing principles into the closest proximity, and thus allow for productive borrowing between the two fields.

Developing effective relations with the client that facilitate design

In order to begin the design process, engineering students must meet with the client for their project and develop an understanding of the project based on the information the client provides. The primary difficulty students encounter here is the inability of the client to specify exactly what he/she wants out of the team or in the final design. Although the client is the one with the problem that must be solved, the client is often unclear in his own mind regarding exactly what is wrong or what the final design should look like. In addition, the client may express ideas that change as circumstances surrounding the project change. As Wojahn, et. al., argue, "students must not only understand the specific problem the client wanted to be resolved" but also adapt to the client's changing demands, "since feedback from clients during a given project may indicate evolving expectations and interests--a frustrating but common experience."[1]

Strategies that could assist students with developing effective relations

Design specifications are the primary design tool for improving relationships with the client during the design process. The assumption underlying synthesis of design specifications is that if the client and the design team can agree to a set of written design specifications, then developing a product that meets the specifications will satisfy the requirements of the client. The assumption is usually valid in consulting relationships where the client is the end user. The assumption is more questionable when the design team is developing a product for a mass market, e.g., a car or personal computer. In these cases, the client is a combination of product managers and marketing who convey the end user's needs to the design team.

In the case of client-sponsored capstone design projects, the student design team is unlikely to contact the actual end-users. For capstone projects use of the audience workshops might help the student design team to focus more explicitly and thoroughly on end user requirements. Quality Function Deployment (QFD)[13] is a methodology that has been developed to help design teams break down end user requirements into a series of matrices that later will help the analysis of tradeoffs when evaluating design alternatives. However, the QFD methodology might be too complex to be incorporated in the senior capstone project. Some combination of audience analysis worksheets and a simplified QFD methodology might provide more effective tools for both designers and writers to strengthen client relationships and consideration of end user requirements.

In addition to the QFD methodology, engineering educators might benefit from adopting for their teaching of design strategies that writing teachers typically use to encourage students to craft documents that will meet the audience's needs effectively. These strategies include an initial analysis of the rhetorical situation (including audience), planning and drafting that takes into account the findings of this analysis, document testing, and final revision to ensure audience accommodation.

One key to an efficient and effective writing process is learning how to analyze the rhetorical situation productively before one even begins drafting a document. Thus, a technical writing teacher will encourage students to determine their target audience, their exact subject matter, their purpose, the genre (memo, report, evaluation, etc.) they are working in, and relevant elements of the context for the writing (such as time or financial limitations). The analysis of audience is particularly key, and writing teachers employ many tools to help students focus on learning more about their target audience. What is the audience's educational level? Experience with the subject matter? Purpose in using the document? Likely attitude toward the subject matter, document, or author? Writing teachers employ tools such as audience analysis worksheets to remind students to attempt to answer these questions about their audience before they begin writing (see Figure 1). Completing an initial audience analysis has various benefits that should be made explicit to students. The writing student will produce a better first draft if he or she has first considered these matters, and then made appropriate decisions based on them. For example, the writer of an instruction manual who has determined that the audience has basic experience with the equipment will not include an instruction in how to turn the machine on, but rather will proceed quickly to the areas of operation that are more likely to present difficulty for the typical user.

Recognizing the value of team work

With recent changes in engineering curricula, many students are assigned to project teams as early as their freshman year. As faculty, when we put students into design teams, we do so to introduce them to the way of working that is typical in the engineering workplace. Very seldom will an engineer work on his/her own to complete a project; instead, a team of engineers (and often other professionals) are assigned to develop a design solution and document it. Unfortunately, engineering students typically receive little in the way of team training, and so they may miss the underlying principle of team work, that a team functions optimally when each team member brings a different perspective to the solving of the problem and that the project itself benefits when each team member possesses a different skills set.

Reader's Name and Professional Title:

1. Operational Characteristics:
    - Reader's role within the organization and consequent value system
    - Reader's daily concerns and attitudes
    - Reader's knowledge of your technical responsibilities and assignment
    - What the reader will need from your report?
    - What staff and other persons will be activated by your report through the reader?
    - How your report could affect the reader's role?
2. Objective Characteristics:
    - Reader's education—levels, fields, and years
    - Reader's past professional experience and roles
    - Reader's knowledge of your technical area
3. Personal Characteristics
    - What personal characteristics could influence your reader's reactions?
    - Age, attitudes, pet concerns, etc.

Figure 1: Audience Analysis Form[14]

Strategies that could assist students with developing effective relations

In writing in particular, all students (not just engineering students) seem to resort immediately to compartmentalizing the writing of a group document. Initially this seems to be an efficient use of the group's time and energy; each team member is responsible for a different part of the document, and the production of the final document involves pasting each part together into a whole. The result of the piecemeal approach is often a document that does not possess a coherent, unified voice or style. Not surprisingly, the document is written by different authors, but little time has been spent on editing the parts together to produce a consistent final version.

One effective strategy we have used in the technical communication classroom is a series of collaborative writing and editing exercises. The strategy first involves providing students with examples of incoherent, non-unified team documents. Students are asked to identify the elements of the document that were authored by different writers but never edited together. As teachers, we refer them to the lack of a single, coherent "voice" or perspective on the information in the document. Then we provide students with a set of strategies that can assist them in writing and editing collaboratively. These strategies help students write better documents while they also emphasize the importance of team work.

The same effort can be seen in the design classroom as well. Engineering faculty may try team work exercises that also help students improve their team skills. For instance, when engineering faculty place students in teams, they might recognize that "Students do not come to school with the social skills they need to collaborate effectively with others. So teachers need to teach the appropriate communication, leadership, trust, decision making, and conflict management skills to students and provide the motivation to use these skills in order for groups to function effectively."[15] As a result, faculty members teaching design courses often must provide some training to assist students in learning to work in teams. Although the range of team training is broad and simultaneously deep, some areas could be highlighted. Effective teams need to develop common goals and common modes of acceptable behavior, i.e., norms.[16] So exercises have been devised for helping teams develop common goals and common norms, colloquially referred to as codes of cooperation.

In order to help students develop team goals, the following exercise may be used. On a sheet of paper, create a column for each team member and a column for the team. Ask each member, in turn, to state one of her/his goals for the course and record the goal in the appropriate column. Repeat a small number, for example 5, of times. Ask the team to select one goal from each column and synthesize the individual goals into a goal to be placed in the team column. Repeat to construct a small number of goals in the team column. Revise the goals in the team to create a set of goals for the team. Each team should then submit its goals to the instructor. It might be helpful to ask each team to revisit its goals after a few weeks and determine if changes are necessary.

In order to help the team develop common norms, engineering faculty may find this exercise useful. Ask teams develop their code of cooperation as a design exercise, i.e., creating an object that solves a problem. Ask each team to develop a consensus list of a small number, e.g., five, behaviors or practices by their teammates that have been or potentially could be problems or interfere with the team effort. Requiring them to pick a small number encourages dialog and helps them determine the most important potential problems for each group. Next, ask them to turn these into positive statements, e.g., "Coming late or missing meeting." becomes "Attend all meetings and be on time." At this point, the instructor may talk about codes of cooperation, possibly providing one or two examples of individual norms, and suggest that the positive statements they have developed could become the basis for a code of cooperation. Ask the teams to consider other potentially troublesome behaviors, generate additional positive statements, and finally agree to adopt their code as a guide for their team activities.

Alternatives Generation

When synthesizing an artifact, either a document or engineering design, one of the processes is generating ideas that will be considered for implementation. Research on writing by Hayes and Flowers has demonstrated significant differences in the planning process. As Bruer noted, "What most distinguishes skilled from unskilled writers, and young from mature writers, is the sophistication of their planning and how they control the writing process."[11] In the Hayes-Flower model the three sub-processes within the planning process are (a) generating content, (b) organizing content, and (c) setting goals. Capability in the sub-process of generating content separates skilled from unskilled writers.[17] Likewise, generating alternatives would, by analogy, distinguish skilled from unskilled designers. Therefore, strategies to improve the ability to generate alternatives whether sentence structure, document organization, technical alternatives, or product presentations will benefit both writers and designers.

Research into the area of generating alternatives has focused primarily on developing individual creativity. In these studies, individuals are asked to think about solutions for a particular problem while considering a specific tool. For example, individuals may be prompted with particular questions.

(i) How might a solution be developed using this material?

(ii) How would this solution differ if the material were changed?

In addition, strategies have been developed to help groups generate alternatives. Two notable strategies are brainstorming and nominal group process. If courses in technical writing include specific reference to both individual and group creativity strategies with opportunities to apply these strategies to specific writing challenges, then the connections that students make between design and technical writing might be strengthened and the quality of both writing and design might be improved.

Usability testing

As technical communicators, we want to help students understand the value of testing their writing on intended readers and revising the document according to reader needs. We teach three kinds of document testing: text-based testing, expert-based testing, and user-based testing. In the text-based approach, the document is tested against guidelines or checklists, often in a class peer review situation. Expert-based testing is achieved by soliciting feedback on the document from professionals either expert in the technical subject matter and/or experienced in producing that particular kind of document/genre (i.e., procedure manual, evaluation report, etc.). One of the most valuable tests of a document, however, comes when the writer solicits members of the intended target audience to use the document in realistic conditions and provide feedback about which aspects could be improved.

One point that we find particularly important as well as challenging to convey to students is that user-based testing is perhaps the most important kind of testing they can do if they hope to produce a truly successful artifact. Students are accustomed to relying on the advice of academic experts (their instructors), and to some extent on their peers, but they are less often placed in situations where they are producing documents for audiences other than their professor. Therefore, they are less experienced in doing the kind of testing that requires them to obtain feedback from real target users of a document. Students need to learn both the importance of user-testing and specific strategies for carrying it out successfully.

In addition to the strategies we have outlined here from the field of technical communication, we find that the field of design offers a number of effective, useful strategies that could help student achieve learning in the area of usability testing. For instance, design projects are customarily subjected to several different kinds of review. First, projects are reviewed with respect to the set of specifications that have been developed for the project. Of course, in the writing process audience analysis is often emphasized to a greater degree than in design process. However, the design process typically places more emphasis on developing a rigorous set of specifications, many of which can be evaluated objectively. For example, does the design function with power from a standard AC outlet? Since a set of specifications have been developed, the design can be tested against the objective (and usually subjective) specifications.

Since all the requirements for a design are not objective, the design team typically schedules several design reviews with the client. During a design review, the team presents the current design and invites feedback from the client. Client reviews are similar to user-based testing in the writing process, but design reviews do not solicit feedback from the people who will actually be using the product. Instead, the client serves as a surrogate for the end user. In engineering practice, the design team may also have opportunities to interact with end users. However, interaction between the engineering design team and end users is rare in practice and it is almost completely absent in capstone design projects.

A third type of review capstone design projects is the progress review. Design teams prepare progress reports and/or hold progress meetings with the engineering faculty member who is teaching the design class or mentoring the specific design team. Progress reviews are held to establish the degree to which the design team is meeting the deadlines that were established at the beginning of the project. Design reviews and deadlines are specific drafts and due dates in writing projects. Progress reviews provide opportunities to provide feedback on the design; however, the primary purpose is to establish accountability for schedule that was established at the beginning of the design project.

Conclusion

As we consider the relations between design and writing in engineering education, we have found that the two fields may contribute significantly both to each other and to student learning. In particular, we see the increasing dialogue between engineering faculty and writing faculty as a productive collaboration that will eventually improve students' educations. We have made only a preliminary study of the strategies currently used in each field, but hope that continued exchange between design and writing will illuminate other effective strategies that will enhance student learning and reflection.

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