DISSERTATION

THROUGH THE EYES OF ENGINEERS: WRITING IN ENGINEERING CONTEXTS

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JON A. LEYDENS ENTITLED THROUGH THE EYES OF ENGINEERS: WRITING IN ENGINEERING CONTEXTS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

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This phenomenological study of writing gleaned understandings from participants about the role of writing in mining engineering workplace contexts and in a university-level project-based senior design (SD) capstone course in mining engineering. While secondary data came from SD classroom observations and course documents, the primary data emerged from interviews with four groups of participants, including SD instructors, students, clients, and alumni. Participants ranged from college seniors to engineering practitioners with between three and over 25 years of experience.

The findings reveal participants' perspectives on SD, socializing forces, workplace writing, rhetoric, writing and thinking, and the value of writing. Participants identified few areas for course improvement and agreed that SD is generally effective in achieving its objectives. Participants also thought that writing played little to no role in facilitating the process of socialization into any given workplace; however, those asked indicated that the way engineers write reflects the degree to which they have been socialized into an organization. Further, participant statements about what constitutes effective workplace writing provide a portrait of disciplinary values and suggest diverse perspectives on the role writing plays in the workplace. On audience and persuasion, participant comments suggest a continuum of rhetorical awareness based on career experiences and organizational roles and reveal diverse perceptions concerning writer identity, the role of objectivity, and the roles of readers and writers. Also, participants

were emphatic in accentuating the cognitive benefits of writing for engineers and also highlighted important differences between visual and textual thinking. Although participants recognized that writing facilitates thinking and career advancement, they also described several reasons for negative attitudes toward writing. Overall, these findings provide initial snapshots of diverse developmental stages at various junctures in an engineering career.

This study has important implications for those involved with engineering education. Understanding engineering students' perceptions of writing in relation to the perceptions of more experienced engineering practitioners gives us a glimpse into how these engineers' conceptions about writing develop and change over time. Such awareness has implications for how educators can facilitate young engineers' growth via writing in the disciplines, metacognitive activities, and other means.

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It was not the first time I had seen it. The averted gaze, head down, tears welling up in his eyes as he clutched the ball even harder, walking off to the side of the house. At the beginning, I had most difficulty taking head on one question: "Dad, how much longer will you have to work in the evenings?" I wondered how to tell my five-year-old son that before I had my evenings back, he would be nine or 10. Five more years to a five year old *is a lifetime*.

I began this Ph.D. program in 1999 while working full time. My son will turn 10 next month, and he has a sister who is now three. I can never recapture the evenings that my wife and kids and I have not spent together. At times I tried to chase away the images of my son sitting alone in a field on his soccer ball, chin in hand. In the last five years, there were fewer games of soccer, dominoes, tag, *gioco dell'oca,* and fewer vacations than I would have liked. I would like to be able to say I did not imagine a small particle of my spirit evaporating every time I had to refuse my daughter when she asked, "Dad, will you read me this book?" I cannot call back the times my wife needed a break from the stress of her career and parenthood, while I was in class, researching, or writing.

If we define our accomplishments in terms of what we had to give up to attain them, this Ph.D. is among the most valuable accomplishments in my life. Without the love, patience, and support of my wife and kids, this Ph.D. would have been impossible. I can only hope my presences have made up for my frequent absences.

To achieve, we need inspiration. My primary career inspiration, Dr. William G. McBride, is now an Emeritus Professor of English from Colorado State. In one of Charles Dickens' novels, the author wonders how differently the course of our lives would have been if we had not met particular people at precise junctures in our lives. Bill McBride was there when I needed him most—and still is. The direction my life has taken since first walking into Bill McBride's classroom one January day in 1983 has been so positive in large part because of his inspiration. In my own way, my career has been an effort to live up to his masterful example as teacher, mentor, and friend. Through his example, I have glimpsed greatness of being, and have learned to focus my energies toward making a difference in the lives of those whose souls are woven in with mine.

I would also like to thank my committee members and particularly my advisor, Dr. Timothy G. Davies, for his thoughtful dialogues during the conception of this dissertation. He made this labor less labored and injected his passion for discovery.

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CONTENTS

CHAPTER 1: INTRODUCTION

Research Problem

This study was conceived out of a desire to better understand faculty, client, student, and alumni perceptions of the role writing plays in a senior capstone design course in a university engineering program as well as in other engineering workplace contexts. At present, while some research addresses the role of writing in developing higher-order thinking skills and in assessing student understanding in engineering courses (e.g., Wheeler & McDonald, 2000), researchers who study writing in engineering contexts lack a more complete sense of what instructors, clients, students, and alumni think about the role writing plays in the process of learning to think and write like an engineer, and in how those diverse perspectives intersect.

In senior design capstone courses that employ project-based learning, the learning process is particularly complex given the nature of such courses. Calls for curricular reform of engineering education generally and design courses specifically from faculty, students, alumni and industry have led to numerous changes in the last decade; much attention has focused on the capstone design course, a course in which future engineers design projects to prepare for the realities of engineering practice.

Researcher's Perspective

Consistent with the precepts of open disclosure within a qualitative design, this section explains the researcher's perspective. I have been teaching for over 15 years, including over 10 years of teaching English courses (including composition, disciplinary writing, and technical writing) at the postsecondary level. Since 1997, I have worked in the Campus Writing Program in the Division of Liberal Arts and International Studies at the Colorado School of Mines (CSM). At CSM, I have also served as the Chair of the Writing Across the Curriculum (WAC) Committee since its inception in 1998. My research interests are in WAC, writing in the disciplines, assessment, and in teaching and learning. I am particularly interested in how novice and other members of disciplinary discourse communities conceive of the role of writing, in writing for non-academic audiences, and in the transferability of writing skills learned in college to non-academic (particularly workplace) contexts.

In terms of writing, I hold a socio-epistemic, or socio-cognitive view, meaning broadly that multiple cognitive and social factors shape the process by which one writes and learns to write in any given context. This research is also informed by research on writing in the disciplines, as explored below. As a researcher, I believe that qualitative, mixed method, and quantitative studies function appropriately depending on the nature of the research questions, purpose of the research, theoretical approach, subjects involved, and other factors.

To imply that researchers have no preconceptions about the subjects and objects of their research is ingenuous at best, so some of mine are briefly stated here. Like other researchers who study writing in the disciplines, I think writing can serve as one of the best vehicles for learning any course content. Writing is frozen thought, and as such allows us insight into the movements of the mind over time. If facilitated appropriately, writing activities can be used not just to demonstrate what one has already learned (i.e., learning to write), but also to assist in learning what one has not yet fully grasped (i.e., writing to learn).

Since writing can help students learn better and teachers teach better, it is a particularly ideal tool in problem-based learning contexts that frequently involve open-ended projects requiring an iterative revisiting of emerging knowledge. Further, some of these contexts involve actual clients and actual projects, which can more meaningfully reinforce the rhetorical concepts of audience, purpose, and occasion to students who may consider those concepts insignificant or contrived in academic writing. Learning contexts that involve writing to both academic instructors and workplace clients also serve as exciting terrain for inquiry because those who study writing in academia can benefit by knowing more about the effect of academic instruction on writing done in the workplace.

Background

In the spring of 1999, the Undergraduate Council at CSM passed a WAC Committee-sponsored resolution that each department or division identify four upper-division courses, generally two junior and two senior-level courses, as writing intensive (WI). The measure had widespread support and faculty continued to express interest in summer WAC workshops. During those workshops, faculty consistently showed preferences for descriptions of actual WI courses as opposed to hypothetical ones, and so began a journey. Since many faculty had been incorporating writing in their courses for years, in academic year 2000-01, I used a portion of a curriculum and program development mini-grant from our Vice President for Academic Affairs to fund exploratory research designed to understand the kinds of WI practices already in place. As Chair of the WAC Committee, I had access to written course descriptions from instructors of WI courses, and I selected one course from each of the 11 departments that grant undergraduate degrees. My hope was that through these examples, faculty in WAC workshops would be better able to understand how writing could serve as a vehicle for learning technical course content rather than drudgery for student writers and faculty graders.

Because I wanted to showcase a broad cross-section of WI courses, my purposeful sample included a variety of course types (field session, lab, senior seminar, etc.), instructional approaches (lecture, classroom/client site, lecture/lab, field work, etc.), and assignment genres (standard engineering reports, literature reviews, progress memos, lab reports, proposals, etc.). After completing interviews with the 11 lead instructors of these courses, I conducted member checking to confirm that the transcribed information was accurate and complete, and I made minor revisions when necessary. These results were posted on the CSM Campus Writing Program web site along with identification of some of the themes and patterns that emerged across courses, such as writing for non-academic audiences (often for actual clients), project-based learning, open-ended problem solving, discipline-specific writing skills, and team writing.

My research interests in writing for non-academic audiences and in the transferability of writing abilities from academic to workplace contexts made me most interested in senior capstone design courses as these often serve as the bridge between college and career. This interest has led me to this study, which could serve as the seed or foundation for several future mixed-method and quantitative studies that will draw heavily from the themes and patterns that have emerged in this research.

Definition of Terms

To understand the nature of these types of courses, it is important to be familiar with the terms capstone, design, and project-based learning. As the word implies, *capstone* in undergraduate education generally refers to a course that synthesizes or sums up students' learning in previous courses and in many ways marks the completion of their academic initiation into that discipline and the launching point into their post-undergraduate, professional career. In engineering, *design* courses generally have as their primary goal the learning that occurs in the process of designing a product or service. For example, students at some engineering schools have designed quieter, more efficient snowmobile engines, solar-ovens for villages in Africa, elementary school playground equipment for disabled and non-disabled children, and so on. *Project-based learning* is a mode of inquiry as well as a way of structuring curricula and features as its catalyst problems from practice that draw from students' existing knowledge. Such problems also demand the acquisition of inquiry strategies that identify and locate the new knowledge needed to solve the problem (Boud & Feletti, 1997).

Purpose of this Study and Significance of the Research

This study focused on how instructors, clients, students, and alumni involved with a project-based senior capstone design course understand the role writing plays in cognitive growth, in students' process of socialization into their discipline and profession, and in academic and industry contexts.

An understanding of the perceived role of writing would contribute to an ever-expanding body of the literature by providing insight into faculty, client, student, and alumni perspectives. These perspectives and their intersections can serve as important foundations for future research. From the themes that have emerged in this study, surveys could be constructed that identify conceptions of writing roles, and these could be used to explore a broader sample if researchers are interested in assessing generalizability. Such results could then inform engineering pedagogy and curriculum reform efforts. The themes that have emerged may also allow researchers to test other hypotheses about the actual and potential role of writing in such courses as well as to apply this knowledge to the assessment of such courses. Furthermore, this study adds to literature on the theories and practices of writing in disciplinary settings generally and engineering specifically. Overall, the study informs the teaching and learning of senior design capstone courses in engineering, especially concerning the role writing could play in such courses.

References

Boud, D., & Feletti, G. I. (1997). *The Challenge of Problem-Based Learning* (2nd ed.). London: Kogan Page.

Wheeler, E., & McDonald, R. L. (2000). Writing in Engineering Courses. *Journal of Engineering Education, 89*(4), 481-486.

CHAPTER 2: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

Much research has informed our understanding of the role of writing both in the engineering workplace and in engineering education. This review of the literature will cover research on writing in the engineering discipline and on project-based learning in design courses.

Writing in Engineering

Studies on communicating and writing in the workplace consistently underscore the important role writing plays in the life of a practicing engineer. Interviews with practicing engineers (Katz, 1993; Vest, Long, Thomas, & Palmquist, 1995) as well as surveys (Benefield, Trentham, Khodadadi, & Walker, 1997; Vest, Long, & Anderson, 1996) have underscored the importance of communication and writing skills for success in the workplace. Other research has shown a direct correlation between the amount of technical communication instruction in college and career advancement (Sageev & Romanowski, 2001). Based on a review of literature on the amount of time engineers write, one study reports that 20-40% of a typical workday is spent writing, a figure that climbs as one moves up the career ladder (Kreth, 2000). A recent study indicates that in their first few years on the job, engineers spend roughly 30% of their workday writing while engineers in middle management write for 50-70% of their day; also, those in senior management spend over 70% and as much as 95% of their day writing (Silyn-Roberts, 1998).

Viewed as a whole, such research articulates the need for and value of writing abilities and rhetorical knowledge for practicing engineers. Other research builds from this foundation to focus on the role of rhetorical knowledge in engineering workplaces, knowledge that complements technical knowledge in multiple and important ways. Rhetorical knowledge here refers to an interrelated network of factors in any writing situation, such as audience (intended reader(s) of a text), purpose (reason(s) for writing), and occasion (the socio-cultural, organizational, political, temporal, and/or other contexts that surround and permeate the act of writing). For example, in one study, effective engineering writers noted that feedback from supervisors and senior colleagues about understanding one's audience helped them become more confident and effective writers as well as more effective members of their organization. They used the rhetorical concept of audience to orient themselves in new workplace contexts and to make sense of rhetorical situations (including notions of writing purpose and genre), both for themselves and later to their junior colleagues (Wilkins, 1991). Other studies have also confirmed the value of rhetorical knowledge in workplace contexts (Vélez & Hall, 2001; Winsor, 1996).

These reports of context-specific learning and the value of rhetorical strategies suggest that engineering educators would do well to focus on developing strategies that writers can use and build on when they enter the workforce, predominantly in the private sector. However, certain obstacles can block the development of such strategies. Studies of engineering courses indicate that some engineering faculty convey messages that de-emphasize and devalue the role of writing and implicitly of rhetorical concepts such as audience, purpose, and occasion—concepts that other studies indicate are central to successful workplace writing (Wilkins, 1991; Winsor, 1996; Chapters 7 and 8 of this study). One of these studies, a longitudinal tracking of students across a five-year period that spanned their academic, internship, and working experiences, found tensions between disciplinary ideology, which suggests to students that engineering texts are arhetorical, and workplace writing contexts, which suggest that rhetorical strategy is important if not crucial (Winsor, 1996). Other studies have highlighted the arhetorical nature of engineering education, perhaps due to the objectivist culture of engineering with its value on detachment and the quantitative (Clancey, 1998) or due to the value and emphasis on the quantitative and graphical as a vehicle for the (intentional or unintentional) marginalization of writing (Mathison, 2000). So while the realities of workplace contexts may call for rhetorical knowledge, structures may be in place that disrupt or prevent the development of such knowledge in engineering education. However, other workplace realities may also be influencing this phenomenon. As the most authoritative voice on engineering writing has pointed out, engineers' use of rhetoric differs from that of scientists because of the material objects engineers work with and because of workplace conditions. Engineers often focus on the production of a marketable object (Winsor, 1998), so

> they have less need than scientists do to create written theoretical work and can, instead, build knowledge by group discussion of instrument traces that they tie directly to the object. The fact that they usually work in hierarchical, for-profit organizations also affects their rhetorical practices, as they must shape the actions of those both below and above them in the organization. (p. 343)

Furthermore, disciplinary instruction or discussion on the effective use of rhetoric may be explicitly avoided in many disciplines, especially in science and technology, because "effective rhetoric involves the denial that one is using rhetoric" (Winsor, 1996, p 7). Some research indicates that engineering students often do not use writing as a tool for learning (Clancey, 1998; Mathison, 2000) and fail to make distinctions between engineering genres (e.g., lab reports written in the same manner as proposals) (Mathison, 2000). The latter study also noted that engineering students did not recognize the role of writing in articulating information more effectively, organizing ideas, visualizing thinking, communicating at a distance, presenting a finished product, gaining understanding, or informing their audience. However, gains in rhetorical knowledge have been observed when rhetorical topics have been explicitly taught in the context of engineering courses (Maharaj, 1994; Ramey, 1999; Walker, 1999). Also, another study has shown that writing can play a vital role, along side discussion and visual representation of data, in the process of engineering design (Lewis, 1999).

The available literature on engineering writing suggests multiple avenues for inquiry, and senior capstone design courses, particularly those using project-based learning and actual clients, serve as fertile research terrain for multiple reasons. First, such courses serve as the synthesis point for a significant amount of prior learning, including the incorporation of technical and non-technical skills (teamwork, communication, etc.) into an open-ended problem-solving experience. Many US engineering programs promote design across the curriculum, so design courses are not novel to some college seniors in engineering. However, few other courses involve such comprehensive syntheses of skills and abilities into a single project. Given the ability of writing to serve as a tool for learning, it can function effectively in courses that place particularly taxing cognitive demands on students in terms of application, synthesis, and evaluation. Whether and how writing serves as a vehicle to higher-order thinking skills in such courses can and should be explored through multiple methods. This study helped create a baseline of the perceptions of the roles writing plays in a capstone design course as seen by instructors, clients, students, and alumni. This perception baseline can then be confirmed, disconfirmed, and/or complicated in future research that assesses actual levels of cognitive growth, degree of socialization into a discipline, and other factors.

Project-Based Design Courses in Engineering

Capstone design courses also merit further investigation because they constitute one of the most significant bridges between an engineer's undergraduate and professional careers. Better understandings about the effectiveness of such courses can provide engineering educators and industry stakeholders with important information about the ability of students to cull a vast array of technical and non-technical skills and integrate them meaningfully in response to an open-ended problem, one that resembles or mirrors the kinds of projects they will encounter on the job. Whether students and alumni perceive writing as rhetorical in this context—which often features an instructor and an actual client rather than an instructor simulating a client—constitutes useful information for students, faculty, and future employers as such an awareness portends greater workplace success. Such information holds value for future studies that assess a type of validity evidence known as criterion-related evidence, which supports the extent to which the results of an assessment correlate with a current or future event (Latcha & Oakley, 2001; Moskal, Leydens, & Pavelich, 2002; Rafilson, 1991). For example, it is common practice in many engineering programs to develop courses that "mimic" the working environment of practicing engineers (e.g., King, Parker, Grover, Gosink, & Middleton, 1999; Sheppard & Jeninson, 1997). Students' perceptions of the nature of their own rhetorical knowledge serve, along with the perceptions of faculty, clients and alumni, as important guidelines in the study of engineering writing. Overall, the questions that scholars have addressed in the literature on engineering writing lead up ideally to a study that culls multiple viewpoints on the role of writing in a senior capstone design course.

Finally, research on writing in the disciplines indicates that disciplinary communities are shaped by their histories, values, and by multiple stakeholders, so the ways of knowing, inquiring, and writing common to each particular discipline vary considerably (Herrington & Moran, 1992; Russell, 1991). This study plays a role in our evolving understanding of how particular disciplinary values shape conceptions of the role of writing, both through the lens of disciplinary insiders (faculty, and possibly clients and alumni) as well as those being initiated into the discipline (students and possibly alumni).

In addition to a review of literature on engineering writing, this study is also framed by the history of engineering education and of senior capstone design courses in particular. In the 1980s and 1990s, industry leaders expressed some dissatisfaction with the level of practical experience of engineering graduates and called for curricular reform (Seely, 1999). Partially as a result of this call as well as recognition for needed reforms from within academia, project-based learning in engineering education generally and in senior capstone design courses in particular has become more widespread. To understand the context leading to this heightened interest in such an approach, a brief overview of the events leading up to the present will be illustrative.

A simplistic view of the events leading to such curricular reforms would posit that post-World War II engineering educators took an analytical, fractionalized curricular approach by dividing various relevant disciplines (math, chemistry, physics, engineering science, and others) into non-integrated components. Aside from some capstone courses, students were to connect hundreds of concepts from these seemingly disparate disciplines together on their own as little or no support for such synthesis was built into the curriculum. In the late 1980s and early 1990s, a major shift took place that promoted a more integrated, holistic curriculum in which science and math were integrated, often in the context of design courses. In these, students framed actual engineering problems and used the tools of math and science (among others) to solve them. Advocates of the paradigm shift promoted "just-in-time" or as-needed learning and a coaching rather than lecturing role for faculty. If it were accurate, this tale of the transformation from analytical to holistic education might continue with early design projects that resembled engineering practice, followed by the logical next step: educators using real—not just realistic—projects, with real clients to make the projects truly authentic.

While this version of the story has some validity, the actual unfolding of events is much less simple and linear. By most accounts, it is accurate that for at least two decades after World War II, curriculum designers placed more emphasis on the rapidly evolving field of engineering science and less on practical learning through design, drafting, surveying, and other hands-on techniques that were part of traditional engineering curricula before World War II (Bordogna, Fromm, & Ernst, 1993; Seely, 1999). But calls to reintroduce such practical components came before the late 1980s. For example, the impetus for the

Engineering Clinic at Harvey Mudd College began in 1962 (Bright & Phillips, 1999). The goals of this project addressed curricular deficiencies by providing students with additional experience with open-ended problems, project skills, and realistic, professional practice—concepts that permeate much of the project-based design literature today. Contrary to what might be expected, industry did not embrace this new curricular approach at first, save IBM, Lockheed, and Beckman Instruments, which did show early support. That the Clinic was novel and had no track record kept investors away initially. Because it was a more resource-intensive form of teaching, industry sponsors were needed, and such support has waxed and waned over the more than thirty-five years of the program, one that is now quite vibrant (Bright & Phillips, 1999).

Also, in 1970, the Education and Experience in Engineering (E^3) Program was developed at the Illinois Institute of Technology (IIT). With concepts also highly reminiscent of today's curricular reforms, the E^3 Program goals included motivating students for "continuous independent learning," facilitating the arrival of interdisciplinary knowledge for problem solving, of self-analysis in students, of multidisciplinary teams, and of diverse communication skills—goals industry and many universities are calling for today (e.g., see Seely, 1999). However, this pedagogical innovation chafed and was extinguished due to several possible factors (Torda, 1999). The established faculty resisted change, and such an endeavor is successful only with both strong leadership and enthusiastic instructors. Conventional wisdom at IIT held that project-based learning would produce engineers with competence gaps. And outside pressure and support for such curricular change was not as strong as it is today (Torda, 1999).

Another aspect of the simplistic version is also more complicated. The idea that learning progressed straight from subject matter divorced from any meaningful context to exercises set in the context of realistic, and then later, real projects is inaccurate. Both the Harvey Mudd and ITT cases indicate that the right industry and academic climate must be in place for project-based learning to thrive. Furthermore, local conditions and resources as well as instructor preferences for realistic vs. real projects determine which type are used. Today, design students explore a broad array of realistic projects, from construction labs that resemble actual work sites (Shapira, 1995) to designing and building model bridges (Mahendran, 1995). Other projects are closer to actual engineering practice and may or may not have an actual client. One design course structure involves modeling and surfactant-enhanced remediation of contaminated soils (Kolar & Sabatini, 2000).

Design students also work on actual projects with non-profit, government, and industry clients. For example, working with a non-profit agency, one student group designed a ticket-tearing device for a physically disabled client (Catalano, Wray, & Cornelio, 2000). Other designs have involved preparation for the Department of Energy's Sunrayce, a solar powered racecar competition (Catalano & Tonso, 1996) and the design and fabrication of wearable computers that have been delivered to government and industrial customers (Amon, Finger, Siewiorek, & Smailagic, 1996). Many design formats are sponsored by government grants, even though the primary collaboration on the design may be between the university and industry. University-industry alliances have led students to design, for example, control systems for stationary diesel engines, waste site remediation projects (Miller & Olds, 1994), fiber optic cable interfaces (Öztürk, Sutton, Vandenbout, Cavin, & Brickley, 1995), smart conveyer belt systems (Jahanian & Matthews, 1999), musical instruments (Jones, Racz, & Rogers, 2001), toys (Latcha & Oakley, 2001) and aircraft (Thompson, 2002). In all cases, however, the choice of course format depends on numerous factors, including the overall curriculum, the availability of sponsors, the availability of faculty for such initiatives, and more.

This discussion of design formats sets the context for the site selection and context of this study, which comes at a time when industry and academic interest in capstone design courses remains high. Yet no studies to date have specifically examined the role of writing in such a course through the perspectives of instructors, clients, students, and alumni.

Faculty members who teach design courses, particularly at the early undergraduate levels, will note that students often struggle with the open-ended nature of design courses and that alumni often describe design courses as among the most useful in preparing them for engineering practice. For example, Harvey Mudd alumni describe their capstone design experiences as pivotal in facilitating the transition from school to career (Phillips & Gilkeson, 1990). However, despite the existence of survey and anecdotal information on the perceptions of undergraduates about capstone design courses, to date there is no rich, thick documentation on instructor, client, student, and alumni perceptions of the role of writing in a capstone design course.

This overview has depicted some existing literature, and consistent with the iterative nature of qualitative research, more literature was reviewed as concepts and data emerged from this study.

Research Questions

This study explores one overarching question with several subquestions. Primarily, the study is asking how instructors, clients, students, and alumni understand the role of writing in a project-based senior design capstone course. More specifically, the research wants to understand their perceptions of the role writing plays in facilitating cognitive growth, in socializing them into their discipline and profession, and in developing their understandings of the exigencies of academic and industry writing.

References

Amon, C. H., Finger, S., Siewiorek, D. P., & Smailagic, A. (1996). Integrating Design Education, Research and Practice at Carnegie Mellon: A Multidisciplinary Course in Wearable Computers. *Journal of Engineering Education, 85*(4), 279-285.

Benefield, L. D., Trentham, L. L., Khodadadi, K., & Walker, W. F. (1997). Quality Improvement in a College of Engineering Instructional Program. *Journal of Engineering Education, 86*(1), 57-64.

Bordogna, J., Fromm, E., & Ernst, E. W. (1993). Engineering Education: Innovation through Integration. *Journal of Engineering Education, 82*(1), 3-8.

Bright, A., & Phillips, J. R. (1999). The Harvey Mudd Engineering Clinic: Past, Present, Future. *Journal of Engineering Education, 88*(2), 189-194.

Catalano, G. D., & Tonso, K. L. (1996). The Sunrayce '95 Idea: Adding Hands-on Design to an Engineering Curriculum. *Journal of Engineering Education, 85*(3), 193-199.

Catalano, G. D., Wray, P., & Cornelio, S. (2000). Compassion Practicum: A Capstone Design Experience at the United States Military Academy. *Journal of Engineering Education, 89*(4), 471-474.

Clancey, S. (1998). "The Handling of Bodies of Alien Men": Ideology, Literacy, and the Production of Engineering Subjectivity from the Michigan Mining School to Michigan Technological University (Technical Communication, Writing). *DAI*, 238.

Herrington, A., & Moran, C. (Eds.). (1992). *Writing, Teaching, and Learning in the Disciplines*. New York: MLA.

Jahanian, S., & Matthews, J. M. (1999). Multidisciplinary Project: A Tool for Learning the Subject. *Journal of Engineering Education, 88*(2), 153-158.

Jones, J. N. I., Racz, L., & Rogers, C. (2001). Musical Instrument Engineering Program at Tufts. *Journal of Engineering Education, 90*(1), 101-103.

Katz, S. M. (1993). The Entry-Level Engineer: Problems in Transition from Student to Professional. *Journal of Engineering Education., 82*(2), 171-174.

King, R. H., Parker, T. E., Grover, T. P., Gosink, J. P., & Middleton, N. T. (1999). A Multidisciplinary Engineering Laboratory Course. *Journal of Engineering Education, 88*(3), 311-316.

Kolar, R. L., & Sabatini, D. A. (2000). Environmental Modeling--A Project Driven, Team Approach to Theory and Application. *Journal of Engineering Education, 89*(2), 201-207.

Kreth, M. L. (2000). A survey of the co-op writing experiences of recent engineering graduates. *Professional Communication, IEEE Transactions on, 43*(2), 137-152.

Latcha, M., & Oakley, B. (2001). Toying with a Capstone Design Course. *Journal of Engineering Education, 90*(4), 627-629.

Lewis, B. J. (1999). Talking to Text and Sketches: The Function of Written and Graphic Mediation in Mechanical Engineering Design (Writing across the Curriculum, Technical Writing, Rhetorical Invention). *DAI, 60*(04A), 332.

Maharaj, S. (1994). A Case for Writing to Learn in the Engineering Curriculum. *DAI*, 300.

Mahendran, M. (1995). Project-Based Civil Engineering Courses. *Journal of Engineering Education, 84*(1), 75-80.

Mathison, M. (2000). "I don't have to argue my design--the visual speaks for itself": A case study of mediated activity in an introductory mechanical engineering course. In R. Andrews (Ed.), *Learning to argue in higher education* (pp. 74-84). Portsmouth, NH: Boynton/Cook.

Miller, R. L., & Olds, B. M. (1994). A Model Curriculum for a Capstone Course in Multidisciplinary Engineering Design. *Journal of Engineering Education, 83*(4), 311-316.

Moskal, B. M., Leydens, J. A., & Pavelich, M. J. (2002). Validity, Reliability and the Assessment of Engineering Education. *Journal of Engineering Education, 91*(3), 351-354.

Öztürk, H. Ö., Sutton, J. C. I., Vandenbout, D. E., Cavin, R. K. I., & Brickley, J. J. J. (1995). A Center for Teaching Design in Electrical and Computer Engineering. *Journal of Engineering Education, 84*(2), 121-128.

Phillips, J. R., & Gilkeson, M. M. (1990, July 1990). *Twenty-five years of experience in a clinical approach to engineering design.* Paper presented at the Frontiers in Education, Vienna, Austria.

Rafilson, F. (1991). The Case for Validity Generalization. *Practical Assessment, Research & Evaluation, 2*(13).

Ramey, D. E. (1999). Assessing writing instruction in a sophomore engineering course: Iterations of integrating writing from 1995--1999. *DAI, 60*(12A), 192.

Russell, D. R. (1991). Writing and the idea of utility. In *Writing in the academic disciplines, 1870-1990: A curricular history*. Carbondale, IL: Southern Illinois University Press.

Sageev, P., & Romanowski, C. J. (2001). A Message from Recent Engineering Graduates in the Workplace: Results of a Survey on Technical Communication Skills. *Journal of Engineering Education, 90*(4), 685-693.

Seely, B. E. (1999). The other re-engineering of engineering education, 1900-1965. *Journal of Engineering Education, 88*(3), 285-294.

Shapira, A. (1995). Bringing the site into the classroom: A Construction Engineering Laboratory. *Journal of Engineering Education, 84*(1), 81-86.

Sheppard, S., & Jeninson, R. (1997). Freshman Engineering Design Experiences and Organizational Framework. *International Journal of Engineering Education, 13*(3), 190-197.

Silyn-Roberts, H. (1998). Using Engineers' Characteristics to Improve Report Writing Instruction. *Journal of Professional Issues in Engineering Education and Practice, 124*(1), 12-16.

Thompson, B. E. (2002). Pedagogy of an Aircraft Studio. *Journal of Engineering Education, 91*(2), 197-201.

Torda, T. P. (1999). An Innovation that Worked--A Useful Reminder. *Journal of Engineering Education, 88*(1), 7-9.

Vélez, L. F., & Hall, S. P. (2001). When a Production Worker is Technically a Writer: Using Craft and Rhetorical Knowledge in a Manufacturing Environment. *Journal of Technical Writing and Communication, 31*(1), 97-111.

Vest, D., Long, M., & Anderson, T. (1996). Electrical engineers' perceptions of communication training and their recommendations for curricular change: results of a national survey. *Professional Communication, IEEE Transactions on, 39*(1), 38-42.

Vest, D., Long, M., Thomas, L., & Palmquist, M. E. (1995). Relating communication training to workplace requirements: the perspective of new engineers. *Professional Communication, IEEE Transactions on, 38*(1), 11-17.

Walker, K. (1999). Using genre theory to teach students engineering lab report writing: a collaborative approach. *Professional Communication, IEEE Transactions on, 42*(1), 12-19.

Wilkins, H. A. (1991). Becoming a Writer at Work: The Transition Experiences of Novice Engineers (Technical Writing, Workplace Writing). 189.

Winsor, D. A. (1996). Do Engineers Use Rhetoric? In *Writing Like an Engineer: A Rhetorical Education* (pp. 1-18). Mahwah, NJ: Lawrence Erlbaum Associates.

Winsor, D. A. (1998). Rhetorical Practices in Technical Work. *Journal of business and technical communication* (12), 343-370.

CHAPTER 3: DATA COLLECTION METHODS

This chapter describes the site, sample selection, participants, and the phenomenological approach.

Site Description

The setting for this study was a senior design course in a mining engineering department at a research university in the United States with fewer than 4000 students. This university grants bachelors, masters, and doctoral degrees in engineering, applied science, and economics and business. This setting was selected because instructors and clients have been using the project-based approach here for several years and their responses about the role of writing would be less likely to be excessively constrained by the immense logistical challenges of initiating such a course. This institution is also known in engineering education circles to be among the most pedagogically innovative. I had professional contacts at this institution, so a rapport had been established with some of the participants. Also, mining engineering is among the oldest of engineering disciplines (unlike, say, environmental engineering) and thus can provide a window into one well-established engineering discipline. This particular senior capstone design course in mining engineering is also ideal because it features project-based learning, writing for actual clients on actual projects, and open-ended problem solving.

Sample Selection Procedures

Sample selection was guided by the principles of maximum variation, serial selection, and continuous adjustment. The idea behind purposeful sampling is to select the sample population that is most likely to detail the many specifics that give the particular context its rich uniqueness (Lincoln & Guba, 1985), and maximum variation sampling is used to document the vast variety of perceptions that come from adapting to the conditions of a particular context (Patton, 1980). In this case, clients, alumni, and students are selected when they seem most likely to hold a wide variety of perceptions and to provide the best information on the role of writing in this context, an admittedly speculative process. One way to maximize variation was through serial selection of sample units (Lincoln & Guba, 1985). This involved selecting each unit of the sample only after the previous unit has been interviewed and participant responses have been analyzed. Each successive unit is then chosen to expand the data already received by, for example, filling in gaps, extending notions of certain concepts, and inquiring about contrasts. This process is supported by Lincoln and Guba's notion of continuous adjustment or "focusing" of the sample as insights and working hypotheses emerge from initial data analysis.

Participants

The primary data source came through interviews with the two instructors who have taught this course over the past several years, two clients, two students enrolled in academic year 2003-03, and two alumni who took the same course in academic year 1999-2000. These alumni had approximately three years of workplace experience and are thus in a position to both recall their senior capstone experience as well as have some professional experience from which to draw while reflecting on the exigencies of academic and industry writing. First I interviewed the two instructors as they act as "gatekeepers" (Creswell, 1998), or authorities who have a significant voice in who becomes and does not become a member of their disciplinary community. The findings and analyses of these interviews shaped the interviews of the next group, the students. Based in part on the findings from these interviews, I decided which of the clients would be most informative to interview. Findings from these interviews also guided the types of questions asked to as well as the selection of alumni. Secondary data sources included fieldnotes I took during SD classroom observations and SD course documents such as the syllabus, writing assignments, and student reports.

The Phenomenological Approach

Given the research questions, a phenomenological approach is the ideal method of inquiry. The study seeks to understand the multiple perspectives of lived experiences of people who have directly experienced the phenomenon—writing in a senior capstone design course in engineering. In this exploratory study, voices of multiple participants culled through a long interview protocol helped to construct an overall portrait of their experiences of this phenomenon.

The data analysis methods described here largely follow ideas described by Moustakas (1994). As noted above, the data analysis methods were iterative and responsive to emerging data. The overall analysis procedure follows several steps that lead to a final goal of describing the essence of the participants' experience of the role of writing in this course.

Prior to data collection, I conducted what Moustakas calls *epoche* or *bracketing,* which involved acknowledging what I bring to the research so I can set aside preconceptions, as much as possible, to best understand the experiences of the participants (see Researcher's Perspective in Chapter 1). To track the evolution of my preconceptions, I also kept a reflective journal that described emerging conceptions of the phenomenon of writing in the study context and featured reflective entries after the interviews and classroom observations as well as entries that revisit the broader initial preconceptions. This macro and micro-focus on preconceptions helped chronicle their development and allowed for investigation into some potential blind spots and fruitful areas of inquiry.

The next eight steps are described in Table 3.1. In *horizontalization,* I listed every significant statement (SS) from the interviews and gave these statements equal value. These statements were then *clustered into meaning units* (thematic clusers, or TC) and overlapping and repetitive statements were be removed within that cluster. From the first few steps emerge the next two, which involve first constructing a *textural description* (TD) or narrative about <u>what</u> was experienced and then constructing a *structural description* (SD) about <u>how</u> the phenomenon was experienced. As noted above, the aim of these steps was to convert the textural and structural descriptions into a brief description that typifies or captures the essence of the experiences of all participants in the overall description (OD). Composite descriptions were then constructed, as noted in Table 3.1 (Moustakas, 1994). This phenomenological analysis procedure described in Table 3.1 has been paraphrased from Moustakas (1994), whose method is itself adapted from Stevick (1971), Colaizzi (1973), and Keen (1975). The acronyms below have been adapted for referential efficiency.

Table 3.1: Phenomenological Analysis Procedures

Analytical Step	Acronym
1. Note all potentially significant statements (SS) in the verbatim transcript, and list each nonrepetitive statement. SS are also called invariant horizons or meaning units, and the term "horizons" underscores the idea that each statement is treated as having equal value. Moustakas calls this process horizontalization.	SS
2. Develop thematic clusters (TC) by clustering the SS into themes.	TC
3. Provide a textual description (TD) by synthesizing SS and TC into a description of the textures of the experience, including some verbatim examples.	TD
4. Reflecting on the TD, provide a structural description (SD) that explores the underlying and precipitating factors that account for what is being experienced; researcher reflections, varied frames of reference, and divergent perspectives can be used to inquire into underlying structures such as time, space, materiality, causality, and relationship to self and others.	SD
5. Construct an overall description (OD) for each participant by combining that individual participant's TD and SD.	OD
6. Construct a composite textural description (CTD) by combining the TD from each individual participant.	CTD
7. Construct a composite structural description (CSD) by combining the SD from each individual participant.	CSD
8. This overall composite description (OCD) of the meanings and essences of the experience of the phenomenon for all participants is a synthesis of CTD and CSD.	OCD

While I planned certain aspects of the data collection and analysis processes, I also deliberately attempted to remain open to the directions suggested by the emerging data, emerging ideas from new literature read as a result of emerging data, and ideas from committee members and other sources.

To verify the trustworthiness of my data, I conducted member checking on the TDs, and invited all participants to comment on the SDs and ODs. Member checking on the TDs enabled participants to provide input on the accuracy of the interview synopses. Further, I also used peer review by asking engineering faculty with some interest in writing to comment on the collective findings of the study. Ultimately, these measures made for more trustworthy data.

References

Creswell, J. W. (1998). *Qualitative Inquiry and Research Design: Choosing among Five Traditions*. Thousand Oaks, CA: Sage.
Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Beverly Hills, CA: Sage.
Moustakas, C. (1994). *Phenomenological research methods*. Thousand Oaks, CA: Sage.
Patton, M. Q. (1980). *Qualitative Evaluation Methods*. Beverly Hills, CA: Sage.

CHAPTER 4: PARTICIPANTS AND RESPONDENTS

After a brief description of the interviewed participants and a discussion of the ways in which the research questions evolved, this chapter will also profile three respondents, engineers who are not faculty at the study site university but who responded to the study's findings described in Chapters 5-10. In those chapters, participant comments constitute the principal data source for the findings, and two minor data sources, observations and documents, are also presented to substantiate and check the primary findings.

Participant Profiles

Senior Design (SD) instructors, students, clients, and alumni will be introduced in the order in which they were interviewed—Rikard, Illan, Michael, Hugh, Byron, Ed, Thomas, and Nathaniel, all of which are pseudonyms. The original interview plan involved interviewing instructors, clients, students, and alumni in that order, but that changed due to logistical constraints and to a desire to first understand SD through the eyes of those most directly involved in it—instructors and students—and then elicit the perceptions of those more distant in terms of time and space from the course—clients and alumni.

All interviews occurred between January and July 2003 with participants who had one of four relations with a SD course in a mining engineering department at the study site institution. Participants included SD instructors, currently enrolled SD students, SD clients, and alumni of SD. All participants were male as no female students were enrolled in the class, and none appeared on the instructor-provided list of former SD clients. Also, no female students were enrolled the year in which alumni took SD, and all SD instructors have been male. Participants ranged from 21 to approximately 60 years old. Each interview took place with only one participant; no pair or group interviews were conducted. For reference purposes, Table 4.1 summarizes the roles and pseudonyms of each participant.

Table 4.1: Summary of Participant Roles and Pseudonyms

Pseudonym	Role in SD	Additional Role Information	Order*
Rikard	Instructor	Current SD instructor	1
Illan	Instructor	Former SD instructor	2
Michael	Student	Enrolled in SD in 2003 (Instructor: Rikard)	3
Hugh	Student	Enrolled in SD in 2003 (Instructor: Rikard)	4
Byron	Client	Supervised the engineering function in SD	5
Ed	Client	Supervised the engineering function in SD	6
Thomas	Alumnus	Took SD in 1999-2000 (Instructor: Ilhan)	7
Nathaniel	Alumnus	Took SD in 1999-2000 (Instructor: Ilhan)	8

* Refers to the order in which the participants were interviewed.

Rikard: Current SD Instructor

Rikard was educated in Europe, and has graduate degrees in mining engineering. He has over 25 years of combined experience in industry and as a university faculty member in Europe, Africa, Australia, and the US. He has industrial experience in coal and hard-rock underground mining as well as in other mining activities. His research has focused on mining, mine design and construction, and construction excavation. Since the mid-

1980s, he has been a faculty member and department head at the university where he now teaches, and he has taught Senior Design (SD) since 2001.

Illan: Former SD Instructor

Illan was educated in Europe and the US and has graduate degrees in mining engineering. His industrial experience was primarily in open-pit mining, and he also has experience with underground hard-rock mines. His industrial experience has also involved ore reserve estimation, mine planning, and geostatistics; in total, he has been in the mining industry for over 25 years. His research has centered on open-pit mining, geostatistical estimation, and other topics. He taught Senior Design for several years until 2001.

Michael: SD Student

Michael was enrolled in Senior Design in the Mining Engineering program during the study period. After graduating with a Bachelor of Science degree in that program, he enrolled in a graduate degree program.

Hugh: SD Student

Hugh was enrolled in Senior Design in the Mining Engineering program during the study period. Shortly after graduating with a Bachelor of Science degree from that program, he began working for a mining company.

Byron: SD Client

Byron is a division president of a Standard and Poor's 500™ corporation that produces chemicals and constructions materials. He has nearly 25 years of industry experience and with his current company has several years of experience supervising the engineering function for SD projects completed by students from at least two universities. He has a bachelor's degree in Mining Engineering from the same university where Michael, Hugh, Thomas, and Nathaniel obtained their degrees, as well as an MBA degree.

Ed: SD Client

Ed has worked in coal mining for over 15 years and served for the first time as the primary mentor for a SD project just prior to the interview for this study. His current company operates several surface coal mines, and he serves as a project manager at one of those sites. He holds a bachelor's degree in Mining Engineering from a university other than the institution from which Byron, Michael, Hugh, Thomas, and Nathaniel obtained their degrees.

Thomas: Alumnus and Former SD Student

Thomas took SD in academic year 1999-2000, graduating with a Bachelor of Science degree in Mining Engineering that spring. He indicated that numerous factors attracted him to and have kept him in mining engineering. He said the fact that a mining engineer must know and be able to combine complex ideas from multiple disciplines such as geology, geophysics as well as civil, mechanical, and electrical engineering to solve problems provides constant challenge and learning opportunities. After graduation, Thomas began working at the same coal mining company with which he did his SD project and where he now works in a leadership role.

Nathaniel: Alumnus and Former SD Student

Like Thomas, his classmate Nathaniel also took SD in academic year 1999-2000 and graduated with a Bachelor of Science degree in Mining Engineering that spring. When asked about his decision to study mining engineering, he also noted that the field's multidisciplinary nature was intriguing. Beyond that, for Nathaniel mining has been a family tradition since the early 1900s, and when he finished college, he and his brother opened their own coal mine after conducting all the exploration work and raising over a million dollars in venture capital. Nathaniel worked as a mine manager until they sold the mine recently. At present, he is a self-employed entrepreneur of a trucking and a construction excavation company.

Results of Member Checking

After each interview, each participant received the opportunity to verify the accuracy of an interview summary. As noted in the previous chapter, this procedure is a form of member checking designed to augment trustworthiness. Six of the eight participants responded to the interview summary, noting in all cases that the interview summary captured the spirit of their thoughts; two participants, Rikard and Ed, elected to not respond to the interview summaries. Among those who responded, a few participants clarified one or two minor statements or phrases, but no participant recommended a major change or revision.

Research Questions Enhanced

The initial research questions for this study entailed one overarching question with several subquestions. Primarily, the study sought to investigate how instructors, clients, students, and alumni understand the role of writing in a project-based senior design capstone course. More specifically, the study aimed to glean participant understandings of the role writing plays in facilitating cognitive growth, in socializing them into their discipline and profession, and in developing their understandings of the exigencies of academic and workplace writing. Of course, in most qualitative research the research questions are not static but respond to and are shaped by emerging themes, and this study was no exception. The original interview questions fell into four primary categories: SD, writing and thinking, socialization, and academic and industrial writing, and these remained relevant themes throughout the study. As knowledge emanating from the participants expanded, that four-category structure also evolved to more explicitly include two additional categories: rhetoric and the value of writing. While these were not explicit question categories in the initial interviews, questions directly and indirectly related to rhetoric and the value of writing were part of those first interviews, and over the course of the study these questions elicited such rich, detailed responses that they morphed into explicit thematic units. Hence, participant comments are presented under six major thematic headings, the foci of Chapters 5-10:

- Senior Design
- Socialization
- Workplace Writing
- Rhetoric
- Writing and Thinking
- Value of Writing

SD and Socialization, Chapters 5 and 6, respectively, provide a framework on participants' overall responses to the course as a bridge between undergraduate and post-undergraduate contexts. In the next four chapters, participants build upon this framework by describing views on workplace writing, a topic on which participant responses were quite elaborate. Their understandings described in Chapter 7, Workplace Writing, help set the stage for the sections on Rhetoric, Writing and Thinking, and the Value of

Writing, Chapters 8-10, respectively, as participant comments on these themes were generally given in the context of discussions on workplace writing, whether that workplace was situated in academia or industry. Although the nature of participants' comments will reveal why these last four sections merit separate treatment, several participant comments appear in more than one section as some comments conceptually straddle and enhance multiple thematic units.

The nature of the interviews also shaped the evolution of the research questions. Qualitative interviews are generally unstructured, semi-structured, or structured (Leydens, Moskal, & Pavelich, 2004). Structured interviews do not allow researchers to deviate significantly from a prescribed set of questions, and while such interviews facilitate cross-interview comparisons, the chief disadvantage is that the researchers' conceptualization of the topic guides the dialogue. By contrast, semi-structured interviews permit researchers to be more responsive to participant conceptualizations of the interview content by allowing for deviations from a set of questions. The interviews in this study were semi-structured. Participants in early interviews played particularly active roles in guiding the direction and nature of the dialogue; yet even in the later interviews, participants still addressed many issues on (as well as not on) the question set without having ever been asked those questions. The interviews did not become completely unstructured, however, as some new questions—many of which had emerged as a result of previous participant insights—entered the question set. For example, comments from the initial participants interviewed regarding visual thinking, translating technical ideas for non-engineers, and writing attitudes all produced questions that were addressed by participants or asked directly to participants in later interviews, and those findings appear in Chapters 9 and 10. All questions sets can be found in Appendices A-D. Because of the desire for participant conceptualizations to make their mark on the interview content, in no interview were all the questions on the question set asked, and often questions not on the set arose spontaneously as a result of participant comments.

Respondents

In addition to the aforementioned primary participants, this study has three additional engineers who read and responded to the findings of this study. Specifically, these three respondents read the contents of Chapters 5-10, excluding my researcher commentary sections at the end of each chapter. Respondent One provided marginal comments, some of which are embedded throughout Chapters 5-10 in italics, and Respondents Two and Three provided end comments, which are included in Chapter 11. Each respondent was selected because of the particular professional background he or she brought to the study, and their feedback serves to augment the trustworthiness of this study.

Respondent One

In addition to over 40 years of experience in the mining industry, this respondent also served for seven years as a professor of a US mining engineering department in which he held an endowed chair position. While in the mining industry, he managed engineering studies, mineral property feasibility studies, technical evaluations, mine developments, and ongoing operations. In academia, he supervised mining research and taught, among other courses, the capstone SD course in a different US mining engineering program than the study site. At present, he is as an emeritus professor, an instructor of online mining engineering courses, and a consultant for international mining industry professionals working in coal, gold, tungsten, and many other types of mines.

Respondent Two

Respondent Two inhabits both the realm of professional engineers as well as the realm of professional technical communications educators. She holds degrees in systems engineering and a Ph.D. in industrial engineering. At present, she is an assistant professor in a department of technical communications at a large public research university. Her research interests include design processes and strategies, educational uses of information technology, learner-centered design, human-computer-interfaces, engineering education, and educating reflective practitioners. Among other courses, she has taught undergraduate courses in information design and graduate courses in the role of human expertise and technical communication and in user-centered design.

Respondent Three

Respondent Three is a Professor of Mechanical Engineering at a research university and land-grant institution. He holds degrees, including his Ph.D., in mechanical engineering. His research and teaching interests are in heat transfer, fluid mechanics, methodologies for engineering problem solving and design, and the role of writing in engineering courses.

With that as preface, let the voices of engineers, interspersed by my researcher commentaries, now speak.

References

Leydens, J. A., Moskal, B. M., & Pavelich, M. J. (2004). Qualitative Methods Used in the Assessment of Engineering Education. *Journal of Engineering Education, 93*(1), 65-72.

CHAPTER 5: SENIOR DESIGN—THE CAPSTONE EXPERIENCE

"...you went to school to become an engineer, and I think the Senior Design capstone course is kind of proving that you become an engineer after four years."
--Michael

Participants' comments on the capstone course in this Mining Engineering Department, Senior Design (SD), can be arranged into four themes: learning benefits, writing, workplace preparation, and overall role responses.

Learning Benefits in Senior Design

To reveal the way in which these perspectives unfolded for me as the researcher, the viewpoints are presented in the order in which the interviews occurred, from instructors and students to clients and alumni. Participants described numerous learning benefits from their senior design experiences.

Instructor Perspectives on Learning Benefits: Academia-Industry Connections

In identifying learning benefits, instructors drew on their experiences in industry and academia. For example, Rikard noted that SD focuses on the process by which students locate and solve real, preferably industrial problems. Solving actual open-ended problems forces students to draw on their problem-solving skills and previous coursework, as well as to involve a network of professionals to assist them, including faculty, the client, and possibly others, according to Rikard. Both Rikard and Illan mentioned that rather than disseminate specific knowledge, SD instructors guide or facilitate students' learning as students explore new technical and non-technical territory. *Respondent One: "I disagree that the student should not be given specific knowledge on how to correctly put together a mine evaluation and feasibility report. This is a golden opportunity to teach them what is required by industry in such a report, but still does not restrain them from solving real mineral industry problems."*

Illan added that his own experience as a student in SD, decades ago at the same university where he now teaches, confirmed the course's value in preparing him for future career challenges. In his own SD project, Illan drew from and synthesized four years of knowledge to produce his first substantial report. "I still have a copy of it. I was proud of it," he said. *Respondent One: "I agree. I even encouraged my students, given the correct opportunity, to show their SD report to their supervisor on their first job: particularly those who had won national competitions."*

Because some other faculty members also recognize the value of SD, their departmental curriculum scaffolds directly to SD, so that core courses "teach [students] [...] how to think analytically and technically" and in doing so prepare them for major courses, according to Illan. Both core and major courses provide them with the foundation and some of the tools necessary to arrive at a viable SD solution. Occasionally, a mistake made early in a SD project has necessitated major revamping. Illan stated that, due to the ripple effect a single major error has induced, some students in the past have had to virtually redo the entire study, including regenerating all the maps and calculations. When students consider these experiences in retrospect, particularly once they are in industry, Illan thinks that they then appreciate having had such experiences. *Respondent One: "I agree. In fact many students have told me that it was the best and most important course that they had taken in college."* Illan noted that in SD students learn first-hand central values of the discipline, especially regarding what constitutes an optimal engineering solution.

In the process of arriving at such a solution, students learn about project management. Once students have found a project and defined its scope, Illan has asked them to list the tasks necessary to complete the project, establish a deadline for each task, and produce progress reports at each milestone on the timeline. Rikard also required similar progress reports, and Illan added that the progress reports allow students to assess their own progress, obtain assistance if necessary, and stay on track. According to Rikard, other aspects of SD help hone additional skills valued in industry; for example, while searching for the right project, students develop both their network of industry contacts as well as their networking skills. *Respondent One: "I don't disagree with this statement, but think that the next statement is overstated, in that the characteristic of being a self starter is not a skill that was developed in SD; rather it simply shows up there."*

Rikard also indicated that their degree of project-finding initiative represents what will become a "natural separation" in industry; the self-starters will tend to be promoted into managerial positions while those who wait for someone to take the lead will make good engineers but will not be promoted as quickly. Through SD, Rikard noted, students develop time-management skills, analytical skills, application and synthesis skills, and oral and written communication skills. Two semesters of SD work culminates in a final report and an oral presentation, during which Rikard stated that faculty from the entire department may ask students "questions from the side," which may "not be strictly related to the project, but somewhat," to see if they can apply a broader range of prior course knowledge to their project. At the oral presentation, students also need to justify the appropriateness of the tools they used to solve the problem, and faculty members provide feedback when appropriate. Rikard noted that in Europe, where he was educated and taught, more professional dialogue occurs between faculty and students than in his academic experiences in the US; European education features more written exams followed by oral exams in which the written exam is discussed and knowledge gaps filled or addressed. In that sense, Rikard stated, the SD oral presentation serves as the closest thing to a comprehensive exam that mining engineering undergraduates will have, since they receive feedback on solving a real, open-ended project from people with various specialties. *Respondent One: "I agree with his final sentence."*

Student Perspectives on Learning Benefits: Project and Time Management

Enrolled in SD at the time of the interviews, Michael and Hugh also commented on learning benefits. In Michael's view, SD teaches students about time management and individual responsibility. He indicated that SD teaches time-management skills because one has to set and meet deadlines while juggling other courses. Also, he liked that SD, which in his case is an individual rather than a team project, teaches one to take responsibility for one's final design, which makes students more attentive. "If something gets screwed up, it's my fault. It kind of teaches you to go back and double-check what you've done and make sure you're comfortable with the numbers." Hugh, in addition to the technical learning benefits he mentioned, agreed with Michael that completing his SD project honed his project and time-management skills. Specifically, he learned how to ask good questions and locate people who were appropriate informational resources. Overall, Hugh said that the course gave him an opportunity to build his resume, network with people in industry, and do something practical, "something that will be used in the real world."

Client Perspectives on Learning Benefits: Utility Beyond College

Both Byron and Ed emphasized the benefits of SD beyond college. Byron noted that students learn how to solve a real problem in industry as well as how to interact in the industrial workplace. Ed agreed that SD helps socialize students into their profession as they gain some valuable experience while solving a real industrial project. Clients' comments on learning benefits were not extensive, as they emphasized other aspects of the SD experience that are discussed below. *Respondent One: "My experience is the same. Particularly where the student has gone to work with an industry consulting group, they hit the ground running and are assuming project responsibilities much earlier than they expected."*

Alumni Perspectives on Learning Benefits: Career Preparation

In retrospect, both alumni see the value of SD, perhaps even more so three years after graduation. Thomas remarked that SD effectively prepares students for the workplace in exposing them to a real industrial problem and to a final report, which is good practice for the problem solving and summative writing common on the job. Nathaniel said he would rank SD among the top 10 of all the courses he took in college because it helped make him into a better engineer. He observed that he had to synthesize and apply a great deal of prior knowledge as well as develop new strategies in solving his SD problem. He also found SD a useful occasion to practice professional presentation. "I invested an incredible amount of time into my Senior Design project, and that definitely helped me [...] to think about how things should be presented [...]." To gain insights on his project, he also sought faculty resources beyond the course instructor, including one faculty member who knew a great deal about his topic. *Respondent One: "I have talked to [...] graduates who stated similar things [...], particularly those who went to work for consulting groups that immediately got involved in property evaluations. As far as getting help from the other instructors, the students knew that when they needed help in a particular specialty, that they should contact the professor who was that specialist."*

Writing in Senior Design

Participants spoke at length about writing in and outside SD, but many of those comments fit more appropriately in forthcoming sections, and hence the brevity of this section on writing in SD. When commenting on the writing students do in SD, participants conveyed a broad range of viewpoints on the utility and preparatory capacity of SD writing.

Instructor Perspectives on SD Writing: Exploring Disciplinary Expectations

Both instructors viewed the writing in SD as an opportunity to more precisely identify writing expectations that run across mining engineering. In their progress reports and in the final report, Rikard noted, students continue developing their notions of effective mining engineering writing, which, unlike legal or literary language, strives to be clear, concise, precise, and unambiguous. Illan added that since SD students write in ways that more closely resemble workplace writing, SD offers more realistic workplace preparation than some other courses.

Beyond the comments regarding SD's preparatory aspects, Illan also commented on how the SD experience made the relationship between writing and higher-order thinking skills become more apparent. He noted that rather than the act of writing facilitating higher-order thinking, many students' fear of writing prevents them from using writing to develop higher-order thinking skills. He said, "[...many] are afraid of writing. They don't know how to do it, and how to choose the words, and they try to be fancy with the words. And it doesn't sound as good, and they struggle. They need to be very clever higher-order thinkers if they have this handicap." However, if students are confident writers, he noted, "if they are brought to the level, it's not hindering anymore; then it can serve as a real effective media [sic] to help them go to a higher level of thinking. The logical writing, logical thinking, logical writing—it works hand in hand." *Respondent One: "In thinking back on all of my SD students, I think about 70% of them were fairly good engineering writers. However, I did hand out lots of direction on how the report was to be formatted, and structured to a standard that I know met industry standards for a mineral property feasibility study."*

Student Perspectives on SD Writing: Role in Cognitive Growth

Students addressed the role writing played in their varied SD experiences. Besides progress memos and the final report, Hugh wrote emails to his client for clarification and other information and emails to faculty when he had questions that involved their expertise. Hugh noted that the writing performed in SD did not play a significant role in his cognitive growth except perhaps for the writing he did to seek information from the instructor or the client; their responses, he said, did help him see different viewpoints. When asked what he had learned about writing as a result of SD, he said that he could not "think of anything in particular." Compared to other courses, SD involved more interpersonal correspondence, he said. Also, he added that the final design report is intended solely for his professors and not really for the client because the client already knows much of the report's contents and may only use it as a reference to document what was done and why. However, the client's company is "more interested in my computer files, Excel files, AutoCAD files, those types of things." Instead, a report for the client would be much more condensed and would contain more procedural detail and fewer conclusions since "it's not my place to make conclusions necessarily; [the clients] are the ones who ultimately have to make decisions. I provide the information," he said.

Respondent One: "[...] SD is an excellent place to introduce the student as to the proper way to prepare a mine evaluation feasibility report. Many mining engineers during their career will have the opportunity to be involved with mine evaluation of some sort, and there are certain things that need to be covered in the resulting report. I'm sorry that Hugh missed learning this."

By contrast, Michael noted overt benefits to the writing. Specifically, the SD progress memos helped him focus his reflection and direction. "By writing down what you've done, what you've found, you know where you've been and what you've already done. You also [unclear] keep it clear in your mind what problems you've had, if you've solved them or not. And also [...] I like to lay out what I'm going to do next." He also said that he finds writing the progress memos reassuring. "Before you write, you're kind of freaking out. It's like, 'ah, I did this, but I still have so much more to do.' Then you sit down and write the memo and think about it a little more. You realize, 'you know, I'm kind of on track here [...]. It's just step by step, I'll get it.'" In addition to these comments on his writing process, he also addressed his writing products, acknowledging that peers and faculty value other course components more than the written products. Speaking about the SD writing component, he said,

> I'd say it's really important, but not primary. I think the primary part of Senior Design is doing good, solid technical work. The writing is important in being able to present that in a way that everyone will understand. Like I say, the point of the writing is to say, 'here's a problem I was given, here's what I did, what I found, and what this means to you.' And to set on record that you've done something.

Respondent One: "I tried to emphasize to my students that their reports represented all of the work that they did. They may or may not have the opportunity to give a presentation on their work. Their feasibility report will have to stand on its own in competition for company funds with other feasibility reports. A poorly written report, where the company executive can't find the answers that he may be looking for, could kill the project."

In many other classes, he noted, more emphasis is placed on learning prescribed tasks, software applications, and presentation skills; however, the final report in SD is evaluated more closely than other design reports in terms of the design's technical accuracy.

Client Perspectives on SD Writing: Academic Audience

Although both clients provided detailed comments about workplace writing, they said little about the writing in SD. Byron indicated that while the students' final SD reports were written more for an academic than a business audience, writing those reports does help prepare students for writing in industry; he noted that it is common workplace practice to compose written summaries prior to an oral conversation or presentation. Ed also indicated that the final SD report was written primarily for their instructor and secondarily for the client; the student who worked with Ed came to the job site and presented his results orally to Ed and his colleagues. Ed added that the progress reports that students write for the instructor help students put in their own words what they have done and need to do, as well as try to anticipate questions the instructor might have, all of which are useful exercises.

Respondent One: "For the projects that [our] students did directly for clients, the comments to me were a bit more positive than those of Byron. Our clients were very pleased with the professional quality of the reports and thought that they were of the quality that they would get from a consulting firm. They did not always agree with the technical solutions that the student developed on extremely complex projects, but that was not a reflection of the report."

Alumni Perspectives on SD Writing: Preparation for Workplace Writing

Like the two clients, alumni comments on SD writing were generally discussed in the context of workplace writing. Like Byron, Thomas indicated that SD helps prepare students for workplace writing since the final report is similar to workplace summative writing. "That kind of formal writing at the end of the class [...] is very valuable [because it forces students] to do an executive summary. I hated them, absolutely detested them. I never understood the purpose of them [then], but they are so absolutely critical." Nathaniel also acknowledged the applicability of SD writing to workplace contexts. Since Nathaniel's project had specific future intentions, he wrote the SD final report as if it were to a client or a financial institution in charge of deciding whether to provide funding to the project. To prepare such a document, he reviewed "real feasibility and pre-feasibility studies that were prepared by world-renowned engineering firms" to understand the common genre conventions. He considered both the SD progress reports and the final report reflective of and thus effective preparation for workplace writing.

Workplace Preparation Aspects of Senior Design

The above discussion of writing makes clear that many participants were interested in discussing the degree to which SD activities and tasks applied to and prepared students for workplace contexts. Beyond writing, participants discussed numerous additional aspects of SD that help students prepare for the workplace.

Workplace Preparation Aspects of SD: Instructor Views

Both instructors prefaced their comments regarding workplace preparation by describing multiple components of the engineering curriculum, of which SD serves as the capstone.

Rikard accentuated multidisciplinary learning since SD can help students see that open-ended problems often straddle multiple areas of expertise. If, for example, students need to speak with one faculty member about underground coal mining and another about the origin of estimating, they gain exposure to the multidisciplinary nature of any project, Rikard noted. Another preparatory benefit is project management knowledge, which students learn about through the SD activity sequence that Rikard described. To solve the problem, students go through a sequence of activities that include contacting the companies, finding the right project, developing a network of people to assist them (clients, faculty, etc.), formulating and understanding the problem, thinking of potential solutions, using tools to develop and evaluate potential solutions, solving the problem, (re)testing the solution, and finally presenting the problem, methods, and solution. Illan concurred that such a sequence resembles aspects of common workplace project management, and his teaching approach in SD involves a similar sequence. He emphasizes to students that they are not evaluated on whether they meet every predetermined deadline but on how adeptly they respond to delays and how they solve the problem, as they would be in industry.

Reflecting on his experiences as a student in SD decades earlier, Illan noted that, "I was able to see how much [SD] helped me in the long run to be able to do that project and write the report and how it prepared me for the things to come." According to Illan, SD has additional preparatory benefits. Through first-hand experience, students reinforce their understanding of three primary criteria for optimal engineering solutions; namely, that they are economical, safe, and efficient. Also through SD, students develop time-management skills, analytical skills, application skills, and oral and written communication skills. Despite this level of task complexity, most students do a good job with the final report, Illan said. Occasionally, clients have even paid for students to come to the site and present their results; on other occasions, he added, students' work for the company has been impressive enough to land them a job offer, which some students have accepted. Overall, Illan indicated that SD gives students real practice for that day on their first job when they are given "a problem, and they have to figure out how to get the answers to that problem, organize that problem [...] go through this whole [problem solving] process."

Workplace Preparation Aspects of SD: Student Views

Students credited SD to fostering their professional growth in various ways. As mentioned above, Michael thought that SD had helped him hone his time-management skills. He added that school is more demanding than the workplace because in school one has to juggle multiple projects simultaneously while in his internship experience, he was able to focus his energies entirely on a single project. Hugh also recognized some preparatory value in SD since it gave him an opportunity to network with people in industry, and do something practical, "something that will be used in the real world." He also foresees being able to use some of the skills practiced in SD later, including computer applications, the practice of evaluating alternatives to ascertain the best one, and cost-benefit analysis. For Hugh, the greatest value of SD comes from sharpening one's problem-solving skills; he noted, "The most important thing you can learn as an engineer is to be a problem solver."

Respondent One: "I think that Michael's internship experience may have not have been typical of many jobs of a mining engineer, in that most are very demanding, handling multiple projects and problems at once. But I agree that SD is about as close as the student gets to this environment."

Workplace Preparation Aspects of SD: Client Views

Although both clients acknowledged that there is no workplace preparation better than working, they also acknowledged the preparatory value of the SD experience. Byron also mentioned that the students' degree of preparation becomes apparent through the SD experience and even more so with interns, and that degree is a factor in future recruitment and hiring decisions. "[The site university] produces a very high-quality student, and we are very pleased in general with the level of student that we get from there, both in their ability to communicate and their ability to do the technical work. We go through a number of students to get those ones that we hire," he said. Byron and Ed agreed that SD helps students begin to be socialized into workplace contexts, especially if students are given a real industrial problem and the companies actually implement ideas from the students' solutions. *Respondent One: "I would agree to the above."*

Workplace Preparation Aspects of SD: Alumni Views

Both alumni commented on the degree of authenticity in the SD project as well as the writing in SD. As noted above, Thomas thinks SD prepares students effectively for the workplace by exposing them to a real industrial problem and to summative writing. Nathaniel concurred that real problems were quite appealing, especially ones with financial outcomes.

> [...] you may or may not be doing [a project] for a client who [...] may be seriously considering about laying down hundreds of thousands of dollars

> or millions of dollars based on your Senior Design project. So it's not like 'oops, I'm sorry.' Or 'oops, damn I just blew my A, and now it's a B or a C because I screwed it up' [...]. There is money on the line. That always elevates the importance of things.

Overall Role Responses

All participants were asked to express viewpoints on areas for improvement in SD, and some were asked about the amount of problem-based learning (PBL) in the curriculum. Their responses reflect the various roles participants play in relation to SD.

Instructor Perspectives: Faculty Advisors and Work-for-Credit Issues

Based on their separate experiences as SD instructors, both faculty members advocated the same course improvement. They both wanted to see SD students paired with a faculty member who has expertise in a key area of the SD project. So if a project involved a great deal of geostatistics, for example, a faculty member with the most significant geostatistics background would serve as that student's advisor, Illan said. According to Rikard, in this scenario, faculty would play a more active advisory role, much like a master's degree advisor but on a smaller scale. That advisor could also point students toward other relevant information resources. Also, Rikard noted, more contact with faculty would help students begin to see that open-ended problems often straddle multiple areas of expertise, and thus they would gain exposure to the multidisciplinary nature of projects.

Both instructors also commented on the feedback they had received concerning SD from students, clients, and alumni. Students have indicated that they like the course and are supportive of the concept, Rikard stated. Their only complaint is that the work involved is not commensurate with the number of credits, and they think they deserve more than three credits total (one credit for the first semester, two for the second semester). Alumni concur that SD provides a good learning experience and that more credit would recognize SD workload realities, Rikard said. Through becoming repeat clients and introducing new project ideas, clients indicate that they see the benefits for themselves, and they also note learning benefits for students. According to Rikard, clients also see that sometimes being a client is difficult when one is juggling too many work-related responsibilities already.

Respondent One: "I agree that three hours is not enough for two semesters of work. The way we taught it was in one semester, for which the student received four credit hours. However, during that semester, the project would require approximately 400 hours of work. Most students took SD their last semester, and they usually were only carrying 12-14 hours that last semester, so the work got done. They too complained that it was the most work of any course that they had taken in college, but many thought that it was worth the effort."

According to Illan, clients don't always provide feedback, but when they do it is generally positive. Sometimes in writing, they note their level of satisfaction with the students' work and occasionally indicate an interest in working with another student in the future. Alumni and students comment on the amount of time and work the course involved, Illan confirmed. In Illan's experience, when alumni comment on how well they were prepared for their workplace responsibilities, they generally discuss not a single course but the overall curriculum.

Illan also noted that faculty within his own department had a range of views on SD. Some even want to eliminate it, and Illan thinks that is because they have not experienced such a course themselves and do not recognize its practical value. By contrast, Illan's personal experience with the course was quite positive.

Respondent One: "Most of [our] faculty supported the SD concept, but we did have one professor [who] thought it a waste of time. He was trained in Europe and worked mostly on very large open pit projects and had probably never done a mineral property feasibility study in his long career. To him, mining engineering was all mechanical problem solving and pit planning."

Student Perspectives: Faculty Advising and Problem-Based Learning

Without outside prompting, both students addressed the issue of faculty advisors, concurring with the SD instructors about the value of such one-to-one contact. Michael said he would like to see

> [...] more guidance from professors. As it is right now, it seems we're kind of out there on our own. We sit there and we'll struggle with stuff for a long, long time, even though [there's] some simple solution; whereas if there were more professor interaction with that, maybe [it would] get us over the humps quicker, but still achieve the same goals that it does now.

Concurring with Michael, Hugh indicated that SD's lack of structure, while useful in certain ways, made the course more onerous than it may have needed to be, especially due to the instructor's lack of availability to work with students. Hugh also struggled for a long time with reworking some of the computer tools that he needed to solve problems. Alternatively, he would prefer a SD course experience that included more direct instruction on relevant issues such as project and time management, different tools needed for projects, etc. It would also be helpful to have more interaction with faculty in the department since "professors have a lot to offer," he said. While he did seek out several members of the faculty during the year, he said that the lack of structured, helpful faculty contact was a disadvantage.

Hugh also provided his thoughts on problem-based learning (PBL) in his program of study. After noting the importance of effective problem-solving skills for success in engineering, he added, "I can say in all my work experience, I don't think I've done really anything that we do in school. It's just completely different problems that you just have to learn how to find the tools to solve them." He added that "in the workplace you're not necessarily given problems you have a lot of experience with, or experience with at all, so if you just learn how to be able to solve problems, then you're way ahead." He thinks that academic PBL experience "helps prepare you for the culture shock of being an employee [...because] your supervisor [will be] telling you what to do, and not giving you the procedures beforehand like a professor would. [In SD, the professor] says, here's the problem, solve it! And it's very similar to what you would find in a working environment." At present, he thinks the amount of PBL in the curriculum is sufficient, and no significant benefits would be reaped by increasing it; he also noted other PBL experiences, such as first and second-year engineering design courses, surface mine design, and underground mine design. Michael agreed with Hugh about maintaining the current levels of PBL; he indicated a desire to have PBL courses balanced with high-content courses. When asked to conjecture on how, three years from now, he would rank SD compared to his other mining engineering courses, Michael said that it would be in the middle "because I think [...having] a lot of these concrete-type courses to get the fundamental concepts down [...] is more important than some of these open-ended Senior Design things."

Overall, Hugh indicated that SD sometimes seemed like a great deal of work for the amount of credit received. In a summary comment, Michael indicated that SD represents a rite of passage. He said he liked

> [...] taking all this stuff you've learned about over the past four years and [...] having to combine it all into this one big project, kind of on my own. I have to do everything myself, with guidance if needed. And [...] it's a capstone course. That's truly what it is because you're taking all this knowledge that you have and applying it to an open-ended problem, and doing what engineers do and come up with some sort of a solution from within. And that's why you went to school to become an engineer, and I think the Senior Design capstone course is kind of proving that you become an engineer after four years.

Respondent One: "I agree with the above."

Client Perspectives: Problem-Based Learning

The two clients differed in their views on whether the amount of PBL in the mining engineering curriculum should be increased. According to Byron, PBL facilitates the kind of learning and thinking that goes on daily in industry. Unlike many textbook problems, which have clear, unequivocal answers, real industrial problems are often full of ambiguity. This is why Byron is an advocate of both SD as well as of increasing PBL in the mining engineering curriculum; he noted that since he completed his mining engineering education in the late 1970s and early 1980s, PBL has become a more common curricular component in engineering programs.

Ed mentioned that as an undergraduate in mining engineering, he had taken two design courses and found them useful. However, unlike Byron, Ed indicated that he was not necessarily in favor of adding more PBL courses to the mining engineering curriculum. Rather, he would like to see them restructured so students could have more time to communicate with clients about the role of coworkers' agendas and the need to justify the rejection of a broader range of solutions. His comment stemmed from his most recent experience, in which the SD student he worked with was mature in attitude and performance and had solid technical skills. However, given time limitations, the student in the final report and presentation made gross assumptions, insufficiently explored a wide range of potential solutions, and did not fully justify the reasons for rejecting some solutions. This weakness was exacerbated in part by the fact that Ed's workload did not allow him to keep up with the student's project. Overall, Ed was not necessarily interested in increasing PBL quantity but in increasing the quality of existing PBL experiences.

Alumni Perspectives: Problem-Based Learning and SD Improvements

As with the clients, alumni also differed in their views on the ideal amount of PBL in the curriculum. Thomas indicated that more practice with open-ended problem solving would better prepare engineers for the realities of workplace problem solving.

> If you are doing [PBL] continuously throughout the first three years of your [academic] career, so that you had an open-ended problem and you began to understand the importance of 'The first thing I do is identify the

> problem and second thing that I do is understand what the deliverables will be,' when you got to Senior Design, it would be second nature.

Nathaniel said he believed in the practical efficacy of PBL. Yet despite a positive overall view of SD, Nathaniel was reluctant to advocate increasing the amount of PBL. He noted that the mining engineering curriculum is already too full and the number of credits needs to decrease, if anything. Also, he thought that a few courses were still in the curriculum for no better reason than because the previous generation had to suffer through them. At the same time, he acknowledged the difficulty of maintaining a four-year engineering program in a world in which knowledge is continually expanding at increasingly rapid rates. His reluctance to advocate increasing PBL levels also stemmed from the fact that some students are not ready to acknowledge the kind of ambiguity inherent in PBL. Such students still want to memorize and fill in the right answers, he noted.

Thomas also gave suggestions for improving SD. Specifically, he said that SD could improve most via two pivotal changes—de-emphasizing the technical aspects and placing greater emphasis on project management. He indicated that some of the technical components that he spent significant portions of time producing were not particularly useful to his client. A greater project management focus would mean SD students would learn more about communicating effectively and thoroughly with the client, understanding the scope of work, making timelines with goals, major and intermediate milestones, and more. Such knowledge could reduce tendencies toward procrastination and all-night cramming, which are common student habits that can become worker practices. Such work habits prevent people from becoming good project managers rather than "heroes"—a distinction he said he has come to better understand through the help of a company mentor.

> When everything goes wrong, the guy comes out here at 2:00 a.m. and fixes the drag line and gets it up and running and everybody goes, 'Ah, yea! You did a fantastic job!' Well yeah, he did. But you know what? It's really crappy that we put him in that situation to begin with, and the unfortunate part is it's self-serving. You do it once, you enjoy the adulation [...] that you get and [...] so you continue to do it that way because you are a hero. Well, heroes are not good project managers.

Thomas indicated that he has relayed the importance of project management back to his SD instructors, and indicated that graduates with these skills provide more value and cost savings to their future employers. "I can't even think of all the money that we spend on teaching people to be good project managers and more importantly, the money we waste on those who aren't." His first two career assignments demanded project management knowledge, but no one had ever taught him that before, he said.

Respondent One: "I agree with the concept presented, but I have always struggled with the amount of time that it takes to teach project management within SD. Even teaching one course in project management would be a struggle since it covers so many aspects of detailed management. Then comes the problem of fitting it into a curriculum that is already over loaded to meet ABET [Accreditation Board for Engineering and Technology] standards. It is not an easy problem to solve."

Observations of SD Oral Presentations

Although participants' interview comments comprise the majority of the findings in this study, observations of SD oral presentations also serve as a data source, and in this instance substantiate participant comments. During the SD oral presentations on May 1, 2003, students made explicit and implicit references to many SD course objectives. For instance, in one team presentation, two students described the methodology they had learned in previous courses and why they thought it was appropriate. This and other evidence of synthesis of tools from previous courses recurred throughout the presentations as students mentioned particular courses by name. Also, evidence that students were expected to transcend course tools surfaced when two faculty members challenged a particular methodological choice, saying that that method overestimates when used for the metal in question. Students in this instance were rather nonplussed because they were not aware of the alternative method, and simply noted that they had learned the method they used in class from a faculty member who was not at the presentation. Many faculty members made notes at this point in the presentation. That the oral presentations resembled a comprehensive exam was also evident from the nature of the question and answer sessions following each presentation. For example, after one presentation, faculty and students discussed disciplinary terminology as they explored the best way to articulate a concept called "optimal cut-off grade." Also, the nature and value of learning by doing was explored. After one presentation, for instance, the presenter's conclusion was that the client must furnish more concrete data to enable further analysis before a decision can be made, a conclusion fully accepted by the faculty.

Researcher Commentary: Values Inherent in Participants' Perspectives on Senior Design

Among other themes, participant comments on SD foreground what participants deem important and value as mining engineers. A better understanding of what participant engineers do and do not value provides windows on disciplinary values through the perspectives of disciplinary apprentices like Michael and Hugh, disciplinary gatekeepers like Rikard, Illan, Byron, and Ed, and those in between like Thomas and Nathaniel. A richer disciplinary values portrait facilitates awareness of the larger contextual arena in which engineering writing occurs. This exploration of participant values entails their responses to three questions, ones that were not explicitly asked but that are implicit in the character of participant responses:

- In what ways is SD valued?
- In what ways do participant comments on SD reflect shared values?
- In what ways do participants differ in their valuations of SD?

Ways SD is Valued

Many participant comments underscore strong valuations of learning by doing, actual projects, practical application, PBL, and close approximations of engineering practice. Confirming these values are stated devaluations of hypothetical, theoretical, and less overtly practical tasks. Such valuations contrast significantly from other, more theoretical fields of study.

Many participants highlighted the importance of learning by doing, especially when it involves actual problems of practicing engineers, not closed-ended or "contrived" ones in a textbook. For example, Michael noted that practice with closed-ended problems prepares one for more open-ended problem solving, and SD involves synthesizing and applying knowledge "to an open-ended problem, and doing what engineers do and come up with some sort of a solution from within." Michael and other participants noted that SD illuminates the multidisciplinary, open-ended, problem-solving, and complex nature of engineering practice. Numerous participants also commented on the value of PBL courses as the problem-solving sequence of activities so closely resembles activities in engineering practice.

Overall, participant comments suggest that some mining engineers value knowledge in ways that differ from other fields. Specifically, in this discipline, knowledge is not necessarily valuable for its own sake, although it may be, but particularly for what it can do in practical and material terms. Recurring through many participant comments is the sense that knowledge is valued primarily as a tool, not necessarily for any inherent value.

Shared Values

One of the most remarkable findings is the degree of harmony among participant comments regarding the benefits and potential of SD. Most of these shared values are mentioned above, but it is worth noting that participants generally concur this course achieves what it is designed to achieve: to provide college seniors with an actual, open-ended problem that requires the synthesis and application of multiple aspects of an undergraduate engineering background, and in the process hone their problem-solving, networking, as well as oral and written communication skills. At the same time, SD provides industry clients with an opportunity to work with and benefit from the labor of an apprentice engineer. Many participants commented favorably on the difficult yet rewarding learning that occurs from making mistakes and working on a project with real outcomes. As Hugh noted, SD helped him not only build his resume, but do "something that will be used in the real world." Nathaniel also underscored the attractiveness of working on problems that could have important material consequences when he noted that clients may invest thousands or even millions of dollars into a project predicated on work conducted in a SD project. And he would know; the feasibility report Nathaniel produced in SD later helped garner over a million dollars in venture capital, which he used to open a mine with his brother, an accountant and lawyer. While participants registered some complaints about the course, overall they seemed quite satisfied with the learning experience in SD.

Different Valuations

Despite these shared values, another recurring theme in participant comments is the notion that we often value what we most need at present. Hence, participant valuations differ because they are each embedded in contexts that require different types of knowledge, which is a function of their current stage in their careers, their knowledge levels, the activities and exigencies of their current contexts, and other factors.

That we most value what we need in the moment is a notion that guides statements made by Michael, Hugh, Byron, and Thomas, for example.

Michael and Hugh's reluctance to recommend additional PBL courses in the mining engineering curriculum stemmed in part from a need for balance between courses that provide deeper knowledge of tool use and those that feature open-ended problems in which tool use is required. That college is often perceived by students as an unreal playground whereas consequences earned on the job often seem more real, immediate, and important may lead one to think that Michael and Hugh, especially given their comments above on PBL, would be in favor of more PBL. However, Michael in particular said that a certain level of comfort and mastery needs to be achieved with some tools before one can be placed into the relatively more chaotic and ambiguous realm of open-ended problem solving. When asked to comment on PBL in the curriculum, Michael added, "I like it as long as before you get thrown one of these open-ended problems, you have some closed-ended ones. I think you need a solid background of concrete things before you can throw in an open-ended problem and expect [students] to do it. But once you're ready for th[ese] open-ended type problems, you can learn a lot [...]."

So what may account for the fact that Byron and Thomas, by contrast, support additional PBL courses in the curriculum? Learner readiness and degrees of tolerance for ambiguity are likely to vary over time, at various stages of one's career, and from individual to individual. Over time faculty and practicing engineers may have difficulty recalling what it was like to be an apprentice of sorts, as college seniors are in engineering disciplines as they sit on the cusp between immersion in academic and workplace contexts. Through experience, we automate a number of complex tasks. For example, most literate people in industrialized countries have used a computer. Many of us may not be able to vividly recall the lack of fluency we experienced the first time we began using a word processor, and would have difficulty cataloguing the thousands of tips, shortcuts, and bits of knowledge we have accumulated over time about using word processing software.

Dissimilarly, a newcomer sitting at the keyboard, opening such a program for the first time, is more likely to be struggling with thousands of learnable items that we have already automated. Some readers may also recall writing on a typewriter, and by contrast the initial challenge of learning to click on icons, save and print files, all of which are now commonplace tasks—if you have done them. Students in the junior and senior years in mining engineering are embarking on initial forays into areas that professors, clients, and to a lesser degree alumni have worked with for considerably more time, sometimes decades. Even in encountering brand new software, engineering professors bring to that learning event a context of having worked with previous software, having solved previous problems with that software, and numerous other experiences, which give them a richer schema and experiential advantages even compared to a generation of students for whom the word software has always been in existence. Because of their greater number of years of experience, professors, clients, and to lesser degrees alumni have automated some tool usage—as well as complex networks of information about when and why to use certain tools and about problem-solving strategies—in ways that less experienced engineers have not.

The PBL Question

The PBL issue can be framed within the aforementioned analogy. Although learning the basics of word processing can still be fruitfully embedded within a larger problem-solving process, some learners prefer to have "safe" and guided practice in learning those basics before it is assumed they know how to use that tool in solving highly ill-defined, open-ended problems. Because students can only tolerate a certain degree of ambiguity at a time, it is possible to overwhelm learners if they are presented with numerous new tools to learn simultaneously within ill-defined problems that require the use of those tools.

However, it is noteworthy that no participants recommended the abolition or reduction of PBL courses. Hence, perhaps the best course of action is to favor gauging the degree of new learning and ambiguity in any course or curriculum to fit—and expand—the learners' levels of tolerance for ambiguity. When faculty members underestimate those levels, they risk boring or not challenging students. Dangers also exist in the opposite extreme, so finding the right balance should remain the objective.

Engineering curriculum designers also run risks if they reduce existing PBL courses or the role of PBL in the curriculum, assuming that role is balanced at present. Academic training has an influence on students' problem-solving habits and routines, and a curriculum heavy on well-defined problems may limit students' ability to solve ill-defined ones. This phenomenon has been noted elsewhere in the literature on epistemological beliefs; for example, one group of researchers observed that because of the academic training some medical students receive, they tend to oversimplify and regularize clinical cases (Spiro, Coulson, Feltovich, & Anderson, 1988). Thus, identifying the right balance between well-defined and ill-defined problem solving is crucial.

Rather than more PBL in the curriculum, students seemed to want a higher quality PBL experience. When asked about the concept behind SD, Hugh noted that

> It's a good idea. I think it could be taught better so that it's...closer to what the Engineering Department does as far as having a weekly lecture, possibly about project management, time management, and different tools they need. I think the mining Senior Design has turned into maybe too much of an open-ended problem, and there's some loss of learning. You don't get the opportunity to interact with your professors as much as I think other departments do, and I think the Senior Design department has [not sufficiently fostered student-faculty interactions] in the past in Mining, which is unfortunate because I think the professors have a lot to offer in terms of experience and practical knowledge [...]. So by not having that interaction, just being left on your own to do the project, you're missing out on some really good mentoring.

When asked whether he had sought faculty assistance, he said

> Sure, I mean I've gone to other professors; I've gone to [Illan] and got his opinion on some things. I didn't find it extremely helpful in that instance, but [...] when I've sat down and met with [Rikard], he's had some really good ideas. But then they kind of die there because he says he'll do one thing for me, and then he gets busy and doesn't do it. So basically I've found it more beneficial just to do things on my own, because it hasn't been a priority for him to help me out.

This higher quality experience could be more likely if an idea that both instructors mentioned were implemented: creating faculty mentors who would function much like master's thesis advisors, only on a smaller-scale project.

Some might counter that the difficulty with such a suggestion involves resources. Faculty members in the department may already be stretched thin and would merit some kind of compensation for taking on this additional responsibility. Yet this resource issue could spur extramural funding searches, both within the public and private sector. Indeed, the private sector stands to benefit both philanthropically by donating to advisor-guided SD capstone experiences that produce more experienced engineers and materially from the knowledge product guided SD students will provide industry clients.

References

Spiro, R. J., Coulson, R. L., Feltovich, P. L., & Anderson, D. K. (1988). *Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains.* Paper presented at the Tenth Annual Conference of the Cognitive Science Society.

CHAPTER 6: SOCIALIZATION

"The guys who have less than a year's experience get yellow hard hats. After you've been there a year, you get a white hard hat. So it's kind of a big graduation thing. You get the yellow hard hats to stand out - everybody calls them 'sunflowers,' just kind of out there in the wind, don't know what's going on [...]. And people give you a hard time."
--Michael

Each academic or corporate workplace has its own climate or culture, and part of becoming a contributing member of any such culture is learning how people interact, solve problems, and work efficiently together. That learning process involves socialization, the process of developing one's potential and learning about one's cultural contexts through social experiences (Macionis, 1993). This section describes participants' notions on the processes by which socialization occurs, including how they think one moves from newcomer status to a more fully accepted member of an organization. This discussion of socialization processes begins with the obvious socializing factor of experience over time and also includes the socializing effects of writing and other factors.

Socialization through Experience

When asked to conjecture how he might view his SD project three years in the future, Hugh said that he would have a broader knowledge base by then and would "say that it was probably incomplete as far as what I did. Based on what I know now, there are a number of things that I left out, a number of dubious conclusions, shaky assumptions that I wouldn't make at this point." As in this comment, implicit in most participant comments was the notion that socialization occurs over time through interaction with coworkers and through learning from experience.

Thomas indicated that the process by which one moves from a newcomer to an accepted member of his organization involves multiple phases. One of the first socializing factors for him was realizing how different departments, such as Maintenance, Production, and Engineering, each have unique cultures. However, he noted, gaining acceptance in each involves some similar processes, such as getting to know people by talking about non-work-related topics. Also helpful in this process is a willingness to ask questions, listen, learn, and not assume you know everything. However, he said that engineers also need, when the time is appropriate, to take risks and speak up if projects are not proceeding efficiently or effectively. That enables others to trust them with future responsibilities. Nathaniel also noted another phase important to socialization. Especially in a competitive economy, he said, one has to be flexible and responsive to the needs of an ever-changing professional landscape. "You have to have a personality like Gumby had body. You have to be able to bend yourself and twist yourself and do whatever you've got to do [...]. You have to be able to put on different hats in different places."

Both faculty members emphasized the benefits of industry experience for helping mining engineers socialize into their workplaces as well as their profession. For example, Rikard noted that in Europe it was very important to have industry experience in order to hold an academic position, but some US faculty do not have it. *Respondent One: "The average number of years of industry experience for each faculty while I was at [name of university] was probably 15 years each member."*

However, Rikard pointed out that all faculty members within his academic department have had some experience in industry. Students gain some industry experience through internships and through the SD experience. The previous chapter addressed in some detail ways in which SD helps socialize students into the profession, mostly by giving them applied experiences in corporate workplaces during which they interact with industry professionals. As Hugh noted, SD "helps you prepare for the culture shock of being an employee [...because] your supervisor [will be] telling you what to do, and not giving you the procedures beforehand like a professor would. [In SD, the professor] says, 'here's the problem, solve it!' And it's very similar to what you would find in a working environment."

Writing as a Socializing Factor

Concerning whether writing plays a role in the process of socializing students into their workplaces and professions, participant viewpoints varied. Some participants indicated that writing plays no role in the socialization process while others said it plays a limited role. For example, Rikard said that writing plays no role that he knows of in the socialization process, and he listed multiple other factors, which are discussed below. Michael did not altogether discount the role of writing as a socializing force, but he indicated that it does not play a significant role in the socialization process except to allow one to identify documents as proof of work experience, but "it's that experience that really gets you accepted." Byron stated that writing plays little to no socializing role.

However, several participants emphasized the role of writing for establishing and maintaining professional networks, which many said are part of the socializing process. Michael indicated that writing plays a role in socialization in terms of email, which keeps people in contact. Hugh also noted networking benefits via email, saying that such writing helps establish and maintain professional relationships, even with engineers who no longer work for the same company. He also noted that poor or unprofessional writing can work against professionals, especially consultants, who could be stigmatized for the rest of their careers. By contrast, Ed said writing does not play a significant role in establishing and maintaining professional contacts, although he did indicate that writing plays a somewhat larger but still minor role with contractors, such as when he is evaluating their responses to a project document outlining the scope of work. Overall, however, he said that it is the contractors' safety records and performance that count.

In commenting on the role of writing as a socializing force, some participants commented on the level of writing expectations in the workplace. For example, in describing a clear, concise document he wrote and presented to team peers during his internship, Michael said that his peers did not comment on the writing clarity because "that's what they expected of me in the first place, so I didn't really get a pat on the back." In contrast, Thomas noted that when he first started with his current company three years ago, coworkers did not expect him to be an effective writer and were "pleasantly surprised that I was able to write in a fairly competent manner." In addition to comments about workplace writing expectations, some participants addressed the role writing plays in informing the mining engineering community about new technologies, methods, and developments, a form of socialization since one's degree of socialization is tied, along with other factors, to one's professional knowledge. Some participants indicated that some new knowledge also circulates via professional journals and via new product information. According to Michael, all historic written data are important to knowledge acquisition, which is another form of socialization. "If you don't keep the written record, people forget what we've already figured out [...] so writing that record of what's happened in the past is important to propagate new knowledge."

Some participants also commented on how writing can be an indicator of the degree to which a professional has been socialized into a given workplace. For example, Nathaniel indicated that over time, newcomers learn to shape their writing to more efficiently meet the needs of workplace readers:

> [...] if you are working at some place, you figure out what that specific company wants or what that boss wants—what can be left out, what needs to be included, and how to economize it. And I think that is especially specific to engineers. Engineers [...] probably more than any other professional, even subconsciously do that—basically edit out the unnecessary details and streamline it, economize it.

Thomas agreed that, as newcomers become socialized into a workplace, their writing changes. In general, he said, newcomers to his organization write documents that are less concise and precise. Since he was hired, his own writing has improved in terms of clarity and concision. Ed also noted that in general the way company engineers write typical workplace documents gives some indication of how long they have worked for the company. More experienced coworkers generally write documents that are easier to follow due to more lucid logic, clearer financial justifications, and greater knowledge of the overall workplace and its operations. Illan added that a professional's confidence and persuasive force in writing comes with experience. Speaking about why SD students give suggestions rather than make strong recommendations in their final reports, he noted that students "must feel quite comfortable to make some strong recommendations. They're not there yet." When asked how mining engineers make a distinction between the writing of insiders and that of outsiders or newcomers, Illan said he was unable to pinpoint specifics.

As suggested above in the discussion on consultants and contractors, writing might also play a role in socialization, particularly in how coworkers interact with one another, as it creates impressions. A number of participants indicated that poor writing can work against one's professional reputation. For example, Thomas confirmed this in noting that people create impressions about coworkers' levels of professionalism from the content and tone of their email messages, among other written products. However, he noted, these impressions can change over time.

Respondent One: "I do not disagree with any of the above. I think we (at least [at our university]) did not do a very good job in teaching students how to write for different purposes. That is why that I tried to teach them in the SD course exactly what should be contained within a mineral property feasibility study report, and how it should be formatted and organized. When they get into their new employment, they can and should learn what is expected of them within that company about writing various types of reports."

Other Factors in the Socialization Process

Participants unanimously listed factors other than writing as most influential in the socialization process, yet which factors mattered most varied from participant to participant. These factors also varied according to the participants' roles in relation to SD.

Both faculty members focused their comments primarily on how students are socialized into the academic environment, yet both stressed the importance of hands-on experience in industry through SD and internships. Additionally, Rikard noted the role of faculty-student and student-student relations during students' undergraduate careers. He said that the department is a small, "family-type" one in which faculty are available and approachable, which facilitates greater faculty-student interactions. Also, he said that students have contact with other mining engineering students through courses, visits to underground mines, student chapter social events and meetings of their professional organizations, such as the Society of Mining Metallurgy and Exploration (SME) and the

International Society of Explosives Engineers (ISEE). Such frequent contact among students has created an informal mentoring network, which facilitates socialization. "We have a relatively good student body, dedicated student body, and by the junior and senior years, they are pretty much committed to the profession," Rikard noted. "And those who are coming after them, they have a good imprint from the seniors." Overall, the socialization process facilitates what Rikard calls "a very gradually increasing or developing love affair with the profession." Illan added that there is good reason to believe that because of the socialization and instruction students receive as undergraduates, once they graduate, "they belong [to the profession]." For instance, he noted that faculty have not had employers indicate that graduates they've hired do not belong to the profession and that alumni have provided positive overall comments about their academic preparation.

When asked about forces that have helped them become socialized into their profession, both students commented on the value of their SD experiences, as noted above, as well as their internships. Hugh considered the internship experience valuable enough to warrant taking a semester off to do it. The process of moving from newcomer to accepted member of an organization really begins with the first job, he said, where coworkers and supervisors build confidence in newcomers through their work performance and gradually give them more responsibilities "as [they] prove [themselves] through [their] work." How engineers interact with coworkers also determines their status as fully accepted members, which underscores the importance of acting confident and speaking up so people know that newcomers are sure of themselves, according to Hugh. Michael concurred on the importance of the internship, noting that in his internship, he saw explicit markers of acceptance.

> They have two different colors of hard hats. The guys who have less than a year's experience get yellow hard hats. After you've been there a year, you get a white hard hat. So it's kind of a big graduation thing. You get the yellow hard hats to stand out - everybody calls them 'sunflowers,' just kind of out there in the wind, don't know what's going on [...]. And people give you a hard time. I was on the bus one day—we took a bus from [a nearby town] down to the mine every day. I came on with my yellow hard hat and a couple of the miners with white hard hats were joking with me. 'Oh, look at that nice yellow hat; we've got to get that a little dirty here.' So getting a white hard hat is one way to kind of graduate. That comes with experience I guess. After you've been there a year, you kind of understand what's going on, know how to be safe, you have figured out how the place works and how people work together to get the job done.

In addition to internships, Michael also listed professional organization meetings, alumni networks, and company-specific language as factors in the socialization process. He described the SME student chapter and annual meetings as great networking opportunities, and he said he goes to monthly SME meetings for a board meeting, dinner, and a presentation. At the 2002 SME annual meeting, he was paired with a mentor, an alumnus of the study site university, who introduced him to many people whom he then recognized at the 2003 annual meeting.

> I could still see how there's a lot of professional relationships [that] get developed there. Finding commonalties. Kind of fun coming out if you're a mine operator and have a problem with water. You walk around; you meet some guy who builds pumps [...]. So I think it's really important. The mining industry is relatively small compared to others, so you really get to know a lot of people. I would say it's kind of key to business - especially when stakes are high and you want to save as much money as you can, [to] keep costs down.

He also indicated that alma mater affiliations have a socializing effect since there are only a few schools in the US that have mining engineering programs, and among those there's a kind of competitive camaraderie. "You go to these conferences - they're always joking, 'Oh, he went to Virginia Tech. I'm sorry.' So I think, you know, [unclear] you have a commonality there, like I know this guy [...] who was my mentor at the SME - he was just a great guy, he went through five some years here at [the study site university]. He understood what was going on. You develop relationships [...]." Michael also noted the importance of language in the socialization process. Reflecting on his internship, he described company-specific jargon that he had to learn.

> Like the way they describe their benches, and the way they describe their dumps, they had a system they use. 'Hauling from the bench three to the A lift at the base of ramp four.' They are all words you understand but you put them all in this one string, and what does that actually mean? Where are you guys driving from, how are you getting there? I didn't understand any of that at first.

Michael added that a certain degree of socialization into the profession occurs during the undergraduate years and that newcomers in internships and at conferences are generally well received. He said, "I think the feeling in the industry is that if you're in a mining engineering degree in college, they think you're on your way."

Both clients indicated that the SD and internship experiences facilitate the socialization process of undergraduate engineers. Although newcomers in his workplace need time to learn company-specific acronyms and ways people describe certain concepts, Ed indicated that much of the language and logic of mining engineering is similar across workplace contexts. He said that newcomers learn company-specific ways of speaking, writing, and interacting by reviewing historic data, being involved in team projects, working collaboratively to solve problems, and demonstrating sufficient data to support their conclusions. Above all other socialization factors, Byron stressed oral communication and interpersonal skills. As in most workplaces, effective colleagues in his company are neither too standoffish nor excessively social. They need to be able to put people at ease, treat others as human beings, and express and support opinions, and in these matters oral communication skills play a significant role, he said. He added that effective socialization also involves recognizing one's role in relation to three groups—one's superiors, peers, and subordinates. Additionally, he said that mining engineers tend to possess different interests than most employees, and finding commonalities, often with other mining engineers in the workplace, tends to facilitate socialization as well. Also fundamental to socialization is the presence of a "champion or mentor" who facilitates for a newcomer an understanding of the workings of the people and procedures within an organization, he noted. Thomas also mentioned how socialization can be greatly facilitated by a mentor, which he is fortunate enough to have at his current company.

Respondent One: "I think what is portrayed on the previous page is pretty typical of the young engineer entering industry everywhere in mining."

During SD students' oral presentations on May 1, 2003, ways in which SD helps socialize students into their profession were evident. The oral presentations themselves have a socializing effect in that mining engineering students and faculty, as well as industry clients, are welcome, and some non-SD mining engineering students attend. Also, other socialization forces were in effect. For instance, one team of student presenters was clearly expected to transcend course tools when two faculty members challenged a particular methodological choice, saying that that method overestimates when used for the metal in question. As other participants have noted, learning to defend methodological and other design choices is crucial to success in engineering. Also, the "comprehensive exam" atmosphere of these oral presentations resembled what students will encounter at both academic and industry conferences or meetings, with brief presentations followed by question and answer sessions. Students were also being socialized into the profession via exposure to precise disciplinary terminology. After one presentation, for example, faculty and students discussed disciplinary terminology as they explored the most commonly accepted manner of expressing a particular concept. Also, students received reinforcement of the nature and value of learning from trial and error. After one presentation, for instance, the presenter's conclusion was that a firm conclusion was impossible until the client furnished additional data to enable further analysis; given the circumstances in question, this "conclusion" was fully accepted and acknowledged as realistic by the faculty.

Researcher Commentary: Socializing Forces in Engineering Contexts

This commentary will explore some of the reasons that may underlie participant conceptions of writing as a socializing force. According to participants, multiple forces socialize engineers into their profession and workplaces, as listed in Table 6.1. Clearly, participants' views on the precise socializing forces vary considerably yet, to some degree, also overlap.

Table 6.1: Participant Views on the Forces that Socialize Engineers into Their Workplaces

- Academic Experiences (Rikard, Illan, Michael)
- Alma Mater Affiliations (Michael)
- Commonalities with Other Engineers (Byron)
- Faculty-Student Interactions (Rikard, Michael)
- Flexibility/Responsiveness to Changing Workforce Needs (Nathaniel)
- Historic Data (Ed)
- Language (Michael, Ed)
- Mentors (Byron, Thomas)
- Oral Communication/Interpersonal Skills (Hugh, Byron, Thomas)
- Recognition of Role in Relation to Superiors, Peers, Subordinates (Byron)
- Risk Taking (Hugh, Thomas)
- SD and Internships (All participants)
- Student-Student Interactions (Rikard, Michael)
- Team Project Experiences (Ed)
- Writing (Illan, Michael, Hugh, Ed, Thomas, Nathaniel)
    - ⇒ Need to Marshal Data to Support Conclusions (Ed)

With some exceptions, many participants were unable to elaborate in detail on what forces socialize engineers into their profession and workplaces. It is worth exploring what might account for these unelaborated responses. They may stem from the fact that socialization happens over long periods of time and is shaped by subtle and mutually formative factors, some of which may be difficult to isolate. Its often gradual, incremental, and complex nature may make socialization a largely unconscious set of processes that participants may not have had the occasion to reflect on. Furthermore, they may have not overtly perceived the need to identify socializing forces or to characterize any phases of socialization. At the same time, awareness of socializing forces seems to be more acute for certain participants, such as Michael, Byron, and Ed, although exactly why is unclear.

The Role of Writing in Socialization

In general, participants in the first several interviews thought that writing played little to no role in the socialization process. With the exception of Illan, the first four participants interviewed did not explicitly mention whether a novice might write differently than a professional with more experience. Since that question was not directly posed to them, I asked some of the last few interviewees if they did not address the issue spontaneously. In each of those cases, they responded affirmatively, even though in most cases their responses did not feature elaborate descriptions of exactly how experienced writers differ from less experienced ones. For example, Ed indicated that generally the way company engineers write typical workplace documents gives some indication of how long they have worked for the company. More experienced coworkers generally write documents that are easier to follow due to more lucid logic, clearer financial justifications, and, he said, "just knowing the overall business and [...] about your workplace and your operation." Participants described "experience" as the broad and primary socializing agent, and may have relegated writing to a minor or insignificant socializing role because they conceived of writing as the act of merely transmitting existing ideas onto paper via word processing. Had they conceived of writing as a tool for learning about technical content and for facilitating socialization into a workplace, writing may have been esteemed differently. Intriguingly, participants often did not envision writing as a significant *socializing force,* even though some participants acknowledged that *written products* are markers of diverse levels of socialization in less and more experienced engineers in their workplaces. Their implicit explanation for these diverse levels seems to be differences that spring from various forms of experience and knowledge, two elements in which some participants think writing plays little to no discernible role. One possible explanation for the disconnect between the idea that writing is not a socializing force and the idea that written products signify various socialization levels is that participants are really saying that *reading written products* is a socializing force. If so, the internalized knowledge from *reading* company documents may play too indirect a role in the process of *writing* company documents to be detected as a socializing force.

Considerable evidence exists to support the claim that writing fosters learning (e.g., Britton, 1970; Emig, 1977; Langer & Applebee, 1987; Zinsser, 1988), a claim that participants agree with, as will be seen in Chapter 9. But writing may also play a more significant role in the socialization process than participants realize, albeit in subtle ways. Research on student learning suggests that literacy involves the development of insights into the *knowledge culture* within specific disciplines (Crosling & Webb, 2002):

> Highly relevant to support and fundamental to academic literacy is the view commonly found in the literature that knowledge is structured in particular ways across the disciplines. Becher (1989), for example, explores the interconnections of academic cultures and the nature of knowledge. For success in their disciplinary studies, students therefore need to adjust their general understandings of academic literacy to those of their specific discipline [...]. (p. 6)

Crosling and Webb (2002) also note that the need to be attuned to particular aspects of disciplinary knowledge cultures has implications for writing in the disciplines:

> Writing takes on different forms across disciplinary fields, and the prevailing view is of writing as a social practice of the particular discipline, rather than a set of skills to be transferred to any setting (Lea and Stierer, 2000). To write suitably, the writer needs to appreciate, *perhaps unconsciously*, the processes and practices through which disciplinary knowledge is represented and upon which it is based, its position relative to other disciplines and the traditions underpinning the preference for certain genres and styles (Swales, 1990; Lea and Stierer,

> 2000). Swales' (1990) view is that although various genres pertain to all disciplines, these are emphasized differently across disciplines. Also relevant in the writing process is the writer's identity and how writers position themselves in relation to their readers [...]. [emphasis added] (pp. 6-7)

To re-conceive writing as more than merely transmitting existing ideas but as a literacy act and a literacy process that involves learning about knowledge cultures brings writing into a different socializing dimension. Focusing on how the acts of writing (and reading) reveal aspects of knowledge cultures renders the role of writing (and reading) in socialization more important. Such a perspective also makes context-specific literacy acquisition a process of learning the values, habits, ways of knowing, and routines of a discipline, organization, or any other contextual setting. Yet regarding socialization, the view of most participants in this study was to envision writing as a simple communication tool. This perspective may stem in part from disciplinary values that were discussed in the researcher commentary on SD and that will be discussed in future chapters. A thorough examination of this participant perspective on writing and socialization could conceivably require exploration into writing-in-the-disciplines, genre theory, activity theory, as well as into studies on writer identities and agency. While such an inquiry is beyond the scope of this study, it is fine fodder for future research.

Although the role of writing should not be disregarded in socialization, it should also not be overemphasized. If every problem to a hammer appears as a nail, every issue to a rhetoric scholar can appear to involve writing. Rather, writing should be seen as one of many complex socializing forces, along with others listed, and not listed, in Table 6.1.

References

Britton, J. (1970). *Language and Learning*. Hammondsworth, England: Penguin.

Crosling, G., & Webb, G. (2002). Introducing student learning support. In G. Webb (Ed.), *Supporting Student Learning: Case Studies, Experience & Practice from Higher Education*. Sterling, VA: Stylus Publishing.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication, 28*(2), 122-128.

Langer, J. A., & Applebee, A. N. (1987). *How writing shapes thinking: A study of teaching and learning*. Urbana, IL: National Council of Teachers of English.

Macionis, J. J. (1993). *Sociology* (4th ed.). Englewood Cliffs, NJ: Prentice-Hall.

Zinsser, W. K. (1988). *Writing to learn: How to write and think clearly about any subject at all*. New York: Harper and Row.

CHAPTER 7: WORKPLACE WRITING

"I figure that [the] attention span that I am going to get from anybody reading my [documents] is at max five to seven minutes, if I've got that long. Most of the time I probably have a minute and a half to two minutes [...]."

--Thomas

One of the primary purposes of SD and the mining engineering curriculum is to prepare undergraduates for the challenges they will face in their future workplaces, whether those are in higher education, or, as they are in most students' cases at the study site institution, in industry. Determining how well undergraduate programs prepare students for their careers is predicated on an understanding of what exactly students are being prepared for, which in turn is shaped by multiple factors. One such shaping factor is the stated expectations of those working in mining engineering. The findings of this section contribute the perspectives of participants on one aspect of the field, workplace writing expectations. The term "workplace writing" has been chosen because it encompasses both types of participant workplace contexts, academic and industrial. In the context of this study, findings on workplace writing expectations are also useful for designers of SD curricula, as SD serves as a bridge between engineers' undergraduate and post-undergraduate careers.

Academic Writing

Participants discussed academic writing expectations largely in the context of how such expectations serve as a bridge to writing done in industry. For example, Rikard noted that although first and second-year undergraduates have few opportunities to write in their disciplines because core and heavy content courses dominate the curriculum initially, students do receive such opportunities in upper-division courses such as mine ventilation, surface mine design, and SD. Illan added that students are exposed to workplace writing in the curriculum in various ways. Faculty share writing from professional journals, and since all faculty have industry experience, they can provide students with examples of corporate writing. Illan noted that many assignments, including SD assignments, are realistic forms of workplace writing, and students "are experiencing what is expected of them when they [begin their careers]."

Students also discussed academic writing. Michael said that in his experience, academic writing primarily involved particular genres, namely summary memos and project reports. The generally brief memos, he stated, entailed three content components, "what I did, [...] what I found, and [...] what this means to me." Also, in addition to some writing for core courses, he had to write more substantial project reports with "graphics [and] text [that] describe what you did and why you did that." Hugh also listed summary memos and project reports as common disciplinary genres, and he also added emails and research papers. Both students identified similarities between academic and industrial writing, a topic explored below.

Although neither client commented extensively on academic writing, both noted that the final reports in SD, since they resembled writing tasks common to their workplaces, were useful in preparing students for writing in industry. In reflecting on their academic and current writing, both alumni acknowledged the applicability of academic writing to workplace contexts and considered the academic writing they did in college effective preparation for workplace writing. However, Thomas indicated that he would like to see academic writing restructured somewhat so it prepares mining engineers for particular aspects of workplace writing. He commented favorably on the writing he did in his undergraduate honors program, and he also saw many missed opportunities to embed writing within mining engineering courses:

> I can remember a very specific assignment where we had to go through different strip-ratio calculations and different orientations on the pit and why you would do one strip ratio vs. the other. We had to do all that, but we didn't have to summarize it in a memo. But if you were at work, what would you do? You'd finish and summarize it and say, 'Okay, I am going to send this to you, and this is why I want to change the orientation of the pit.'

Respondent One: "[As...] I said above, we do not do a very good job of preparing the engineer for different types of writing."

Writing in Industry

Participants' reports about academic and corporate writing indicate a great deal of similarity regarding genres and audience expectations. In terms of genres, Rikard recalls that a majority of the writing he did while in industry involved brief in-house memos. Illan concurred, noting that in industry he had primarily written brief memos with supporting technical appendices. However, he added that unlike most academic writing, workplace writing often involves writing to non-engineers so, for example, he had to "translate [technical language] into the language that higher management can understand."

Both students identified similarities between their academic writing and the writing they had done during their internships in industry. Michael stated that in his experience, industrial writing often contained the same content components as academic writing, a problem statement, a problem-solving method description, and a statement of results and their meaning. For example, during an internship with a coal company, he had to conduct a study to determine the ideal bench height. He wrote a one-page memo describing the problem, his findings, and his recommendation, and attached the memo to supporting data (maps, hauling simulation graphs, etc.). Also during that internship, he wrote to and received from co-workers daily email memos that described progress to date on particular projects. Although he did not see large reports in that internship, he did help generate data for some medium-sized reports, including a truck weight/truck payload study, which "was mainly tables showing numbers, statistical analysis, and [...] basically all it said was 'we fixed the problem we had earlier.' We [...] needed the truck weight study to verify that."

Of the genres Hugh mentioned as common in academic writing, he anticipated that in industry he would be most likely to continue writing brief memos and emails, and possibly technical reports. He indicated that industry writing will also include written justifications for purchase requests but will not involve the types of writing he did in liberal arts courses, which included defending an opinion, analyzing a group of people, or composing policy-oriented papers. Rather, he said, workplace writing will be entirely technical. *Respondent*

One: "This is not always true! If one has the experience of building a mining town "from scratch" in an isolated area, you would find that many, many things that you must write about, perform an analysis and sell to management have to do with the social system which you are establishing. Believe me, compared to the technical problems, these are complex." The workplace writing Hugh did during his internship mostly entailed documenting what he had done for future reference. The most significant piece he wrote described his analysis of coal haul procedures at the mine and provided his recommendations for improvement along with his conclusions.

Clients also identified genres similar to those named by other participants, although Byron's list of common genres closely reflect his leadership position within his company. He said that besides email, common workplace genres include capital requests, occasional notes to customers, and monthly and annual reports that include past results and future objectives. Ed noted that his workplace writing consists primarily of genres such as email, expenditure authorizations, and an occasional larger technical report, which, including graphics, may exceed 30 pages. Generally, he said, writing describes past, present, and/or future events by providing historic information, current progress updates, and/or planned objectives; writing may also seek to elicit information from the recipient(s).

The alumni's lists of genres differed slightly from each other. Like Byron, Thomas occupies a leadership position with his company, although at a lower hierarchical level. Thomas noted four common workplace-writing genres—email messages, meeting minutes, memo summaries, and authorizations for expenditure. Generally, memo summaries briefly describe the problem, results, and recommendations for future actions; expenditure authorizations provide a primarily economic rationale for a purchase, he said. In the past three years, as a former mine manager and a currently self-employed entrepreneur of a trucking and a construction excavation company, Nathaniel has written primarily in one of five genres—email, legal or other letters, introductory letters, resumes, and regulatory compliance forms. Legal letters primarily include work completion notifications, while introductory letters and resumes facilitate networking. The "cookie-cutter" regulatory forms are for proof of compliance with government requirements. Almost all of this correspondence is between one and two pages in length, he said.

Effective Workplace Writing

Participants also commented on what they think it means to write like a professional mining engineer. According to Rikard, writing in professional mining engineering contexts comes with a definite set of expectations. Unlike literary or legal writing, it should be precise and unambiguous. Furthermore, to be persuasive, and especially in time-pressured industrial settings, it should be concise; "[...] if it is longer than a page or two, nobody reads it," he noted. *Respondent One: "I do not agree with this. The Executive Summary may be only two pages, but the full report needs to be lengthy enough to properly cover the subject!"*

Illan commented on what constitutes an effective technical report, which "put[s] the problem in a larger perspective," and in which writers use their own words. He said that less effective reports do not "flow" effectively and feature introductions adapted from a sample introduction in which writers "tried to add some additional sentences [but] they are disconnected because it's somebody else's writing that they are trying to merge with their own writing." When asked to describe effective mining engineering writing, he indicated that it was no different from any other kind of engineering writing. "It has to be factual and somebody has to understand what they did. They have to be able to communicate the past, what they did, how they did it, when they did it." When asked to describe "flow," he said that includes a "full vision of what that report should be" and at the outset an indication of "how it all fits together."

Students also gave portraits of disciplinary writing expectations. Michael noted that the point of writing in his field is to convey the problem, method, results, and implications of those results. He also spoke of certain types of content that are of particular interest to mining engineers. For example, in the sample geological feasibility report he brought to the interview, he distinguished between sections of the report that would be of interest to geologists and those of interest to mining engineers. "You put stuff in about geometry, which is what the mining engineers care about. They care about how big, what kind of attitude does it have, 'cause that all has implications on what mining method you're going to use to extract the mineral." He noted, "I wrote this in a really mining engineering type tone; I didn't use a lot of big geology words. I'd like to be able to give this one to my classmates and they kind of get [unclear] the gist of where this deposit is, what it looks like, what that means [...]." He added that in mining engineering writing, "it is very typical to have the conclusion at the very end" [of brief documents], which may include conclusions under different possible scenarios. When asked to describe effective mining engineering writing, he noted the importance of writing "as clearly as possible. I think that entails keeping your sentences fairly short, not just all simple noun-verb sentences, but kind of take everything in little chunks, try to explain in a logical way [...]. And I think not getting too bogged down in language. Try to make it as simple as you can. There's no need to put a bunch of fluff and fancy words in there." He also indicated that when they read a technical piece, engineers expect the information to be "clear, succinct, and believable [...]. It has to be good so people can read it. So yeah, something I understand [...]. People [...] won't feel it's very valid if it's not presented in a clear way that makes sense to them. I think [in] writing something, of the utmost importance is conveying ideas and techniques. You have to write well in order to do it." His own writing is effective

> [...] when it flows [...]. I always read it back to myself. I don't say it aloud. I say a lot of it in my head though [...]. And I just [...] make sure that logical sequence is there, combine sentences if it makes more sense to do so. Break them apart if it makes more sense to do so. I think pauses are big. Like when I get to a comma, I pause for a second. When I get to a period, I pause for a little longer time—in my head. And [...] when I can read something and it flows well, in my ear in my head, I think, 'that's nice, that's clear.'

Hugh also described his notions of effective writing, which must be understandable, well organized, concise and precise "because people don't have the patience [or the time] to read something over five or six pages." He reiterated that visually representing key data is a better way in many cases of communicating than putting the data into words. One of his criteria for effective writing in mining engineering is based on whether he can understand what is being portrayed on a first reading. "If [...] I have to read a number of times, it might be that I just need that time to understand, but also I think a lot of times it's writing that didn't quite get to me like it should." However, identifying whether his own writing is effective or ineffective is more challenging, and like many writers, he often relies on input from other readers. Effective writing is also persuasive because workplace audiences expect texts to provide concrete, definitive recommendations so supervisors have to do less work.

Both clients also commented on their notions of effective writing in their respective workplaces. Byron indicated that readers in his workplace expect writing to contain short sentences, vocabulary that is appropriate for the intended audience, and grammar and punctuation that does not seriously distract from the process of conveying the idea. Ed said that effective writing in his workplace does not "get too detailed and bogged down" but provides readers with an overview featuring concise coverage of the main historic and technical points. To write effectively in his workplace, he agreed that one must either consciously or unconsciously internalize readers' expectations, and like Byron, Ed emphasized the importance of writing to diverse (non-engineering) audiences. Their additional comments on audience and purpose are detailed in the section below on rhetoric.

The degree of elaboration on the topic of effective workplace writing varied significantly between the two alumni. Nathaniel indicated that he likes written communication to meet professional presentation and readability standards, but did not elaborate extensively on what those entailed, except to say that communication creates images of one's level of professionalism, and careless communication can create a negative impression.

For Thomas, workplace writing has three primary purposes—to inform, document, and persuade. Informative communication gives progress reports so co-workers are kept up to date on projects that concern them, and documenting information provides a historical record for future reference, especially for safety and legal reasons, he said. Documentation also allows one to set, justify, and work toward objectives, and persuasion occurs in written work that also informs and documents, often in subtle ways, he noted. He added that effective workplace writing entails five main criteria—it is concise, precise, logical, visual, and conclusive; conclusive means that the writer provides a clear conclusion or recommendation. Of those criteria, he commented extensively on concision, which overlaps with other criteria such as logical and visual. Recently, he was asked to a meeting so he could summarize numerous company options contingent upon different customer and competitor options. "It was a really unique challenge because there was such a massive amount of information; to try and put that into a two-page memo was virtually impossible." To convey more information in less space, he compiled an options flow chart that more concisely and precisely illustrated the various if-then relationships, and his general manager said he would pass this document along to the company president. Brevity in writing stems from the exigencies of the workplace, he said:

> I figure that [the] attention span that I am going to get from anybody reading my [documents] is at max five to seven minutes, if I've got that long. Most of the time I probably have a minute and a half to two minutes [...].

He added that writing seems to be even more concise when it emanates from individuals higher up in the company hierarchy.

He also said that visual communication is often the most efficient and effective form of conveying information:

> [...] the old adage [...] still holds true: 'A picture is worth a 1,000 words.' I can say in a table or chart what would take me a page to say in a memo. If I want to show, for example, the different alternatives in productivities that are associated with them, I can spend a page and a half explaining that. Or I can

> put one graph that is a bar chart and they get it. They can look at it and go, 'Okay [finger snap], I understand that alternative has the best productivity.'

On the topic of concision, he also mentioned a nine-month capital justification project in which he had to summarize in two pages all work completed in that period as well as why it took nine months. He noted that "if someone looks in the file, and they see a five-page document, they won't read it." But they would be more likely to read a two-page summary of capital justification, he said. The expectation for concision is not limited to words but also includes visual images. "The key is to be able to summarize a spreadsheet in a one to four or five-line table [...]. When you are writing, you've got to be clear and some times the clearest way to present an option or value of something is in a short table. So, short, clear, logical." To illustrate, he described an unclear technical document written by a contractor:

> I spent an hour going through his numbers, going into his appendixes and looking at his numbers, figuring where he pulled things, doing the calculations myself, and finally figuring out what those four or five paragraphs mean. I sent it back to him, and said, 'You've got to fix this; I am not sending this to my boss. If he gets lost on this, he's going to throw it back at me and say [participant's name], you're an idiot. Don't send me this crap if you want me to read this.'

While the final document of a project may be brief, the volume of data behind that document is not. His recent nine-month capital justification project featured a one-page summary, a three-paragraph letter to a finance officer, an appendix with six or seven pages of text with tables and charts, and a twenty-page addendum with spreadsheets and calculations. "And that doesn't include the three-ring binder that is actually behind the project that I have spent nine months building."

Amount of Writing and Workplace Writing Satisfaction Ratings

In light of their above statements about workplace-writing expectations, some participants were asked how much they write on the job and the degree to which the workplace writing they read meets the criteria or expectations that they had articulated. Ed indicated that 3-5% of his average workday is spent writing, including email. Regarding the workplace writing criteria he described, in Ed's view, about 75% of the documents he reads from others in his workplace meet these criteria.

In his position as the president of a major division of his company, Byron estimates that including email, less than 10% of his day is spent writing. While a typical mining engineer in his company may do less writing as he or she advances, the writing he or she does will tend to be more strategic and vital to the organization, such as annual business plans, he said. Byron added that he has two primary frustrations with writers in his workplace: emails that are either distributed too widely or that are excessive in length and information that is not—but should have been—distributed as background before a meeting. However, overall he has few complaints about the effectiveness of workplace writing; occasional business writing courses serve merely to give reminders about how to organize certain formal documents, but generally workplace writing meets his expectations.

Thomas indicated that on average he spends 15-20% of his day writing, and that most workplace documents he writes are half a page to one page. He estimated that at least 75% of those documents are sufficiently technical that someone would need either an engineering degree or extensive mining experience to understand them. Despite the occasional exception, he stated that a majority of the documents that he reads meet standards for effective workplace writing.

Because Nathaniel is currently in a career transition, the amount of time he spends writing at present is "very little," and much of his current writing lies in the gray area between workplace and personal writing. Some of his formal written correspondence involves contacting former associates, acquaintances, and friends as well as writing for legal matters. Although generally satisfied with the workplace correspondence he receives, he finds two aspects frustrating: that some writing is either overly simplistic or uses unnecessarily inflated vocabulary. Engineering readers are particularly interested in seeing figures that describe economic viability, and he thinks overall standards for written communication are lower than usual right now because of time-crunches stemming from a sagging economy.

Since it has been some time since they have worked in industry, both instructors described student writing, which they say varies greatly in quality. Illan indicated that his difficulty in assessing whether the writing of senior students is like the writing of practicing engineers stems from his workload realities, which have forced him to delegate the reading of much student writing to graduate teaching assistants.

Researcher Commentary: Workplace Writing in Engineering Contexts

Of the numerous issues that have emerged in participant comments regarding workplace writing, two will be explored here. The first considers participants' diverse understandings of the roles that writing plays in workplace contexts. Some comparisons of less and more experienced engineers may give clues as to how these conceptions could change over time. The other area examines participant comments regarding disciplinary values, comments that expand beyond the initial values portrait that emerged in their discussion of SD in Chapter 5.

Textures of Awareness Regarding the Roles of Writing

Participants' responses concerning workplace writing indicate various textures of awareness about the complex roles writing plays in engineering contexts. As one might expect, the engineers with more years of experience generally have more elaborate notions about the roles of writing while younger engineers have relatively less elaborate notions. For example, many of the comments on engineering genres from Hugh indicate that he recognizes differences in the surface characteristics of genres in technical and non-technical fields, but not in the deeper structural elements. He indicated that industry writing will entail multiple genres but will not involve the types of writing he did in liberal arts courses, which included defending an opinion, analyzing a group of people, or composing policy-oriented papers. Rather, he said, workplace writing will be entirely technical. This somewhat rigid division between technical and non-technical genres may miss multiple, important similarities—for example, that most genres require careful audience analysis and the marshalling of (technical and/or non-technical) data to support claims that are subject to interpretation. Hugh also stated that the workplace writing he did during his internship mostly entailed documenting what he had done for future reference. Yet what is "just documenting" to an intern may be much more to the practitioners in an organization. That documentation can play a role in an organization's history and identity as well as in the wider body of texts that can be interpreted, negotiated, and renegotiated over time. This perspective, however, is not likely to be rendered clear to an intern who works on a few projects over a six-month period, but it is to longer-term employees who consciously or unconsciously track the evolution of the organization longitudinally through texts and other means.

Also on a relatively simplistic level, Michael held a one-size-fits-all approach to genres, indicating that virtually all scientific and engineering genres can be written using the same basic template: a problem statement, methods description, results, and discussion of the result's meaning. While this statement contains some truth, it does not reveal multiple important nuances, some of which emerge in other participant comments. (However, this does not imply that Hugh and Michael are completely unaware of more macro-level workplace writing issues; for example, Hugh highlighted the importance of persuasion in workplace contexts, and Michael emphasized how mining engineering audiences have different expectations than audiences in geology.)

In contrast to the students, however, participants with relatively more career experience did have more elaborate notions of genre and of the role of writing. One example appears in examining Byron's notions of the roles of writing and how various genres are embedded in complex webs of audience expectations and purposes. Even though Byron spends less than 10% of his day writing, he notes that a typical mining engineer in his company may do less writing as he or she advances; this notion contrasts with the trend noted in Chapter 2, which suggests that the percentage of time devoted to writing increases as one advances in one's career. But, Byron added, as an engineer advances, the writing that he or she does tends to be more strategic and vital to the organization, such as annual business plans. Byron also noted that his two primary frustrations with workplace writers involve issues of audience and purpose, namely, emails that are either distributed too widely or that are excessive in length and information that is not—but should have been—distributed as background before a meeting. In short, the students' descriptions of workplace writing contain more descriptions of surface characteristics while more experienced participants tend to describe more incisive rhetorical principles.

However, this difference between younger and more experienced engineers is to be expected to some degree. Since the process of conveying concepts in writing involves a great deal of choice making and problem solving, the literature on problem solving is relevant here. Perhaps not coincidentally, research on experts and novices in diverse fields indicates that novices tend to approach problems by exploring surface characteristics while experts often approach problems by identifying more incisive underlying traits or principles (M.T.H. Chi, Feltovich, & Glaser, 1981; M.T.H. Chi, Glaser, & Rees, 1982). Another reason for this difference likely stems from the obvious fact that more experienced engineers tend to have read and written more engineering documents, and it is reasonable to assume that such reading and writing practice will augment one's reading and writing abilities over time. A brief summary of research on the role of reading and writing experience in effective and ineffective writers (Bruning, Schraw, & Ronning, 1999) accentuates this point:

> Generally, good readers are better writers than poor readers. Correlational studies have indicated that measures of reading comprehension are positively related to writing ability (+.50 or above) and to students' beliefs about their ability as writers (Shell et al, 1995). These relationships are not surprising when we consider that frequent reading exposes students to many more samples of writing [...]. At least indirectly, reading can teach students about good writing. It likely also helps students' abilities to detect errors in text and

> monitor comprehension, which relate to revision and writing quality (Beal, 1996; McCutchen, Francis, & Kerr, 1997).
>
> Better writers also have done more writing. [...W]riting is a complex cognitive skill and, like any other skill, improves with practice and feedback. (p. 303)

Unlike college seniors, experienced engineers have the benefit of feedback from colleagues in their workplaces as well as intimate contextual knowledge that fuels a more elaborate sense of audience and purpose.

Values

Participant statements regarding workplace writing expectations stem from particular contexts in which these mining engineers work and have worked, from the history of the discipline, and other influences. One of those influences is shared disciplinary values, what the members of the mining engineering field deem important. In discussing SD, participants expressed valuations of learning by doing, real over hypothetical tasks, practical application, PBL, and close approximations of engineering practice. Confirming these values were stated devaluations of hypothetical, theoretical, and less overtly practical tasks. From participant comments on workplace writing and elsewhere in this study, a richer values portrait emerges that reinforces and adds to the understanding of the contexts in which mining engineers work. Specifically, their ideas about the contextual exigencies in which writing is produced and read reflect particular values, including

- Product or Goal-Orientation
    - Efficiency
    - Utility
    - Problem-Solving Abilities
- Time as Money

The ability to problem-solve, use tools, and maintain efficiency can be seen as subsets of goal-orientation because they each facilitate goal achievement. As with participants' comments on SD, participants here stress utility, which implies that many engineers do not value knowledge for its own sake as much as they value it for its ability to serve as a practical tool for problem solving. Learning by doing is a recurring value, rendered important in this context because it is part of the trial-and-error process and helps hone the kinds of skills and abilities that enable engineers to solve problems and achieve goals. Given close industry-university ties, it makes sense that among the seemingly core values of the field is the notion that time is money; contracting and other engineers understand the concept of billable hours, which underscores the importance of efficient, non-wasteful practices. That time is money is particularly relevant to understanding the exigencies of workplace writing. The bottom line and time pressures influence the need for documents that are quickly accessible. Above, Thomas noted that five to seven minutes may be the most he can expect from a workplace reader, and in many cases the time is two minutes or less. The influence of time on workplace writing also fuels an apparent difference of opinion between Rikard and Respondent One, who seem to disagree on common workplace writing document length. In fact, this may not be a disagreement but a difference in emphasis. Rikard, who did not disagree that workplace documents often have brief summaries and lengthy appendices, emphasizes the brief summary as the document most workplace readers will have time to examine carefully, whereas Respondent One emphasizes the importance of the relatively lengthy supporting documentation as validation for conclusions described in the summary. In contexts in which time is money and success is measured largely in terms of the bottom line, writing needs to conform to the expectations participants mentioned above. In short, audience expectations grow out of the myriad exigencies of any particular context.

The notion that time is money also reinforces and is reinforced by many of the other values—utility, goal-orientation, learning by doing. Further, these mutually formative values are solidified by the reality that engineering goals are often material goals with tangible outcomes, either products or product-oriented deliverables; for example, mining engineering reports might end with the number of tons of coal that can be mined and hauled in a given time period using recommended methods, along with a description of associated cost savings. Although partial, the core set of values mentioned here is particularly understandable given that all academic faculty in the department and all participants in this study have worked in the exact context in which the vast majority of SD students will soon find themselves—in for-profit corporations.

Reflective Vignette 7.1: Member Checking and Literacy Cultures

I have wondered whether one reason many of the participants of this study did not initially respond to my request for them to verify the accuracy of their interview statements stemmed from the fact that they inhabit a different knowledge and literacy culture than I do as the researcher. Throughout the interviews, participants stated that workplace writing must be short or it will not get read. By precise and concise, they generally meant a page or two.

Although I was aware of that when I sent them the interview summaries, most of which averaged five pages, I also was aware that condensing their statements excessively would lose essential richness and multiple important nuances. I wondered if our literacy cultures had clashed.

Also, some participant statements straddled multiple themes. For example, a participant insight may simultaneously be related to the themes, "Workplace Writing," "Value of Writing," and "Audience." Although I also realized that what may be important overlaps in one knowledge culture can be seen as time-wasting redundancy in another, I left in some repetitive quotes or paraphrases so participants could inform me if I were misinterpreting or taking their statements out of context.

Only Michael, Hugh, and Thomas responded without prompting beyond the initial email request. Most others responded after some prompting, sometimes after several weeks and multiple reminders, and two participants, even when they were told their silence was a *de facto* assent that the summaries were accurate, elected not to respond.

Participants may have been eventually motivated to read above and beyond the typical page limit because they had a stake in making sure their ideas were restated accurately and because the reading was not highly complex or outside their realm of knowledge.

References

Bruning, R. H., Schraw, G. J., & Ronning, R. R. (1999). Writing. In *Cognitive psychology and instruction* (3rd ed., pp. 295-319). Upper Saddle River, NJ: Prentice Hall.

Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 1). Hillsdale, N.J.: Erlbaum.

CHAPTER 8: RHETORIC

"[...] if you really want to be effective in persuasion, they can't know that that's what you're doing. When you get up and do a presentation, that's much more difficult to conceal, but in writing it's much easier. You can persuade someone in writing and lead them to the conclusion that you want them to get, without them ever really know what you are doing."
--Thomas

Participants commented on multiple rhetorical issues, most notably audience and persuasion. Audience refers to the readers or recipients of a text, and persuasion refers broadly to the act of eliciting change in the way readers think and/or act. Audience and persuasion are discussed separately below because some participant comments relate primarily to one or the other. But this distinction is also somewhat forced as the two concepts are intertwined; for example, some participants noted that persuasion is most likely to occur if audience expectations are met. Also, many participant comments on audience were embedded within comments on persuasion, or vice versa. Hence, in much of the discussion below, conceptual overlaps occur.

Audience

In their comments on the issue of audience, participants provided views on engineering workplace audience expectations, consequences of not meeting and benefits of meeting those expectations, as well as audience issues surrounding the SD final report. This section also features participant comments on writing to non-engineers and on the degree of importance participants placed on the notion of audience.

What Engineering Readers Want: Perspectives on Audience Expectations

This discussion will be brief because audience expectations were discussed in some detail in the previous chapter. Participants commented on the textual features that readers in the various workplaces expect. The most recurring descriptors were of writing that is clear, logical, concise, and precise, and each of these terms are intertwined, since, as participants noted, concision can bring about clarity, and precision can render more transparent the problem-solving logic. Because of these expectations, participants gave particular caveats against writing that contains "fluff," content that does not directly, concisely, and precisely address the main points. Participants also commented on the nature of the vocabulary, which might be highly technical but must be understandable to its intended audience and not feature what Michael called "fancy words." Given significant time-pressures and readers who expect one or two-page summary documents, workplace writers often summarize main points and omit detailed descriptions, some participants noted. Workplace writing often contains similar features, such as a problem statement, description of work performed, progress to date, and conclusions or recommendations, often with supporting technical data appended. Collectively, the presence of these textual features help make workplace writing more believable, valid, and thus persuasive.

Consequences of Not Meeting Audience Expectations

What happens when writers do not meet, fully or partially, the aforementioned audience expectations? Participants indicated a range of potential consequences. Rikard said that, "I do know from my side there is a great frustration for a reader [in determining] what the heck [the writer] wants to tell me," and others commented on similar frustrations. For example, one of Hugh's criteria for effective writing in mining engineering is based on whether he can understand what is being portrayed on a first reading. "If [...] I have to read a number of times, it might be that I just need that time to understand, but also I think a lot of times it's writing that didn't quite get to me like it should." Such frustrations may lead engineering readers to question the validity of technical ideas.

Michael noted that engineers will be more persuaded if they get what they expect, and that, "people [...] won't feel it's very valid if it's not presented in a clear way that makes sense to them." Byron said that not considering audience expectations can bore, confuse, and/or annoy one's readers, in all cases reducing the engineer's effectiveness in seeing his or her ideas come to fruition. Similarly, Ed indicated that failure to consider audience expectations can result in reader misinterpretation, lack of interest, or lack of approval to pursue a project or acquire equipment. "Somebody [...] really keen on who their audience is may have the better chance of getting something pushed through rather than someone who gets too detailed [...and] loses their audience."

Respondent One: "I agree with the above in that you as a writer must know what your audience expects and write to that expectation. If it is your boss, then you had better know *what he is expecting. If it is an article in a technical journal, then you need to be aware of what is expected by your peers. That is why peer reviews are so important. After a few rejections, you learn what they expect."*

Benefits of Meeting Audience Expectations

Participants also addressed the opposite issue: what happens when writers do meet most or all of the aforementioned audience expectations? Since, as Michael noted, engineers tend to be more persuaded when they receive what they expect, certain benefits accrue to effective writers, according to the participants. While working in industry, Illan's writing facilitated his standing within his company. He indicated that he would spend a great deal of time crafting his writing so it concisely and precisely conveyed his ideas. His memos, he said, were one of the reasons he was promoted while working in Colorado. "I caught the attention of higher management [in the San Francisco office…] which prompted them to go figure out who I was." That reputation also helped him later obtain his academic post, and the president of the mining company he worked for also wrote a letter in support of his tenure years after he had left the company. Illan thinks that in one's career "writing is very, very critical," and he tries to encourage mining engineering students to write more while they are in school so they will have a competitive advantage in the workforce.

Given the intense time pressures on the job, Ed found it helpful "knowing [who] your audience is, and getting it right the first time, not only with writing but assembling our data or heading forth on a project." He also remarked that colleagues with a reputation for clear, logical writing gain respect because workplace writing reveals "what type of person you are […and] what kind of thinker you are and how you go through the [problem-solving] processes. I think that conveys a lot of information to upper management as far as what type of work you have done." He added, "I know certain people I work with, I am impressed with their ability not only because they can write a document, but the process that they follow in their thinking and logic."

Thomas commented that many of his colleagues know him largely from his writing, which has enhanced his professional reputation. *Respondent One: "This is an extremely important point."* Indirectly, participants intimated that many of the benefits of meeting audience expectations are the inverse of the negative consequences mentioned above. That is, documents that meet audience expectations, in part because they minimize reader frustration and the potential for misinterpretation, tend to be seen as more valid and persuasive. Hence, such documents generally increase the probability that engineers will see their ideas come to fruition.

Audience and Purpose of the SD Final Report

In addition to audience expectations, some participants discussed the intended audiences for the SD final report, and participant perceptions varied considerably as to its primary and secondary audiences. In terms of writing in SD, Rikard indicated that audience "does not have much role in their written documentation—very close to nothing." In Illan's view, the instructor reads and evaluates the final report as the facilitator, but the primary intended audience is the client, who sees the information in the report as the main deliverable in the client-student relationship.

Michael described the primary audience of the SD final report as the instructor, and the secondary audience as other mining engineering students. Only when asked about the clients did he note that they are also part of the intended audience "because they actually plan to put this mine into development at some time or other, so I need to be sure I get them the information that they actually need to do that." When asked about the purpose of the SD final report, Michael indicated it was to get a grade from the professor and, secondarily, for the client's company to use as they deem appropriate. Similarly, Hugh thinks of his audience for the final report as faculty but not primarily as the client because the client already knows much of the report contents and may only use the report as a reference to document what was done and why. However, the client's company is "more interested in my computer files, Excel files, AutoCAD files, those types of things," he said. By contrast, a report for the client would be much more condensed and would contain more procedural detail and fewer conclusions since "it's not my place to make conclusions necessarily; [the clients] are the ones who ultimately have to make decisions. I provide the information."

Adding to the complexity of viewpoints on the audience for the SD report, Byron said that SD students are still writing primarily to an academic audience, but they are moving toward considering industry audience expectations. Correspondingly, Ed noted that SD students are writing their progress reports and the final report primarily to the instructor, who serves as their project mentor. The client serves as the secondary audience. He added that at the end of the project, the student traveled to Ed's company site and delivered an oral presentation to some of Ed's colleagues.

Since there was disagreement among the instructor, students, and clients about the intended primary and secondary audiences, the alumni perspectives were of particular interest. With three years of industry experience, alumni are situated between the students and the clients in terms of experience.

Because Nathaniel conducted his SD project for a business venture he intended to pursue after graduation, the SD instructor was a secondary audience, as Nathaniel had in mind his eventual audience, a financial institution. "The way I wrote that was like it was going to be for a client," he said. "Even, I wrote it with a client in mind and financial institution in mind. My goal was to have that be a bankable document. In other words, if I had [taken the study] to a finance company or a bank, [...they] would [...] review it, and it was written and prepared in such a way that they would be willing to actually loan money based on that report." By contrast, Thomas was not writing to a bank or financial institution, although he was hired just out of college by the company for whom he conducted his SD project. Thomas said that he considered the SD instructor "the bigger [...] audience we were trying to satisfy." However, he felt that the client would have played a more central role as the intended audience for the SD final report if SD had been structured to include more elements of effective project management.

> The mistake was up front [...]. Did we sit down with the client and understand what their needs and desires were? Did we ever put a scope of work together? I mean I have written a lot of scope of works [...] since I started working. I never wrote one in college [...]. Why didn't I write a scope of work when I did my Senior Design [project]? I don't know; I just didn't.

Although interviews constitute the primary data source for this study, relevant documents were also collected, and two of those suggest that what is meaningful and important to

Thomas three years after college differs from his ideas as a college senior. Above and at other junctures in his interview, he lamented the lack of project management elements in SD, including such elements as scope of work statements, timelines with milestones, and progress reports. Prior to any interviews, Illan gave me a copy of his SD Course Overview from academic year 1999-2000, the year Thomas and Nathaniel were enrolled in SD. In that Course Overview, Illan wrote that "students need to provide a project completion schedule with duration and completion dates" on tasks they identify as milestones on their timelines. Students were also required to provide project updates and "meet with the instructor every 2 to 4 weeks (depending on a given task) to review the completed task as defined in the project schedule." The second document relevant to this discussion is Thomas' SD final report, which in its Executive Summary contains a section entitled, "Scope of Work." What may be most significant in this instance is that while Thomas is now acutely aware of the importance of effective project management characteristics, at the time he was in SD, those same elements were not meaningful enough to be recalled three years later.

Respondent One: "I have several comments on [...] 'Audience and Purpose of the SD Final Report'. While most of our SD projects were not for a specific client, some were. But it didn't really matter, since I instructed all of my students to prepare their reports as if they were having to prepare them for the eventual use of the Board of Directors of the company that was going to use the report (real or fictitious). I further told them that mineral companies often have many projects being evaluated at the same time and that they were all in competition for the same investment dollar; thus even if all showed profitability, only the most attractive would go forward to the next step of evaluation or design and build."

Writing to Non-Engineering Audiences

In addition to their views on audience expectations and SD audience issues, participants also commented on what many described as one of the engineer's tallest rhetorical challenges—writing to non-engineers. When writing to non-engineers, lay, or non-expert audiences, "you must use language that is not packed with the technical slang," Rikard said. He added that explaining technical issues in common, plain English is "probably the most difficult [type of writing] for an engineer." Exploring why this might be so, Illan noted that writing to non-engineers can involve "translat[ing technical language] into the language that higher management can understand."

Byron underscored the importance of being able to communicate effectively to diverse audiences, from the hourly employees who many not have a high school education all the way up to senior management. He added that engineers must learn to convey technical ideas to non-technical audiences since they may have to convey engineering concepts to colleagues with backgrounds in marketing, finance, accounting, law, and more. "Without that engineer being able to communicate to a diverse group [...] their ideas would not go beyond the lines of a piece of paper," he said.

Ed concurred with other participants that non-engineers are perhaps the most difficult audience with whom to communicate. As an example, he said that writing expenditure authorizations to an investment committee requires meeting the expectations of co-workers with primarily a financial background, which makes them interested in issues such as "cost per ton or cost per hour [...] and rate of return and NPV [net present value]. They are less inclined to know about the break fate of a truck or certain transmission [...] although you can cover that [...] without getting too detailed." In that sense, Ed agreed with Illan that conveying technical information, which is often visual (maps, charts, tables, etc.), requires an act of translation when one is communicating to lay audiences in non-technical terms. This is difficult because occasionally specific technical terms cannot easily be explained. Ed also recognized the importance of conveying ideas to multiple audiences with diverse expectations. "A lot of our writing is for management here, also for Maintenance and Production. Again, see if we are doing bullet points for a mine plan, it's going to be very specific to Production people [...] whereas if Maintenance reads that, they're probably just going to skim through it." Given intense time pressures, he indicated that it helps to know as much as possible about diverse audiences.

On this latter point, Thomas agreed, noting that he composes company-wide emails with greater attention to tone and the impression he is creating than with emails to colleagues within his work group. Thomas also noted that different divisions of his company, such as Maintenance, Production, and Engineering, each have unique cultures, and communicating with each requires different approaches and understandings of particular audience expectations. He also considers the level of technical background in his intended audience. With technical readers, he said that he leaves out most background information and provides visual data with more information density. Workplace readers generally expect visual information because it can often convey an idea more efficiently and effectively, he noted. However, since engineers tend to think visually, he said they sometimes overwhelm non-engineers by dumping too much data into charts and tables. With ill-defined audiences and less technical readers, he includes more introductory and concluding information. Nathaniel agreed on the necessity of crafting writing differently for engineers and non-engineers, noting that

> with engineers you could kind of cut out the padding and go right for the crux of the matter, and maybe spend the excess time you have on more technical details, whereas with a lay audience you are going to want to present in a more marketable fashion [...] kind of steer away from the technical. You are going to have to give more background information, more padding, and of course take the technical details a lot slower.

Respondent One: "You must cover the subject in enough detail that it will be fully explained; if that gets technical, so be it. For mineral property feasibility and evaluation reports, there will be people who will understand the technical and financial items that are presented. If the client does not understand the technical aspects of the report, he can always ask for an explanation of what he does not understand. But if something critical is omitted or glossed over because it is too technical to understand, then he will not ever know anything about the problem and may find out after the plant or mine is built. At that point, the persons who did the study are legally and financially liable for what the client was not told because it was too technical. It is permissible to place some lengthy, technical calculation in the appendix to keep the main report somewhat concise. As to writing it for the future lender, I guarantee you that every bank or lending agency has qualified technical people that will be examining the feasibility report."

Degree of Importance of Audience

Participants indicated that understanding audience expectations plays a role in effective written communication, but they varied in the degree of emphasis they placed on this role. Both students discussed audience issues in texts they had written fairly recently. In the sample geological feasibility report he brought to the interview, Michael distinguished between sections of the report that would be of interest to geologists and those that would be of particular interest to mining engineers, as noted in Chapter 7. "You put stuff in about geometry, which is what the mining engineers care about. They care about how big, what kind of attitude does it have, 'cause that all has implications on what mining method you're going to use to extract the mineral." Referring to his feasibility report, he noted, "I wrote this in a really mining engineering type tone; I didn't use a lot of big geology words. I'd like to be able to give this one to my classmates and they kind of get [unclear] the gist of where this deposit is, what it looks like, what that means." He added that this paper had a dual audience. "I think it would help us, the mining engineers, understand the geology aspects a little more and geologists can kind of understand what we care about as far as the geology." However, Michael acknowledged that effective writing is difficult to produce because you have to think like your reader. "Especially if you've spent months and months working on this and you understand it inside out, it's kind of hard to take a step back and pretend you're someone else."

For Hugh, his recent experience with a text conveyed some unanticipated audience expectations. During his internship, he was asked to analyze an alternative haul route and write a summary of the advantages and disadvantages of various routes. Upon reading the text, his supervisor replied, "OK, which one should we do?" Hugh indicated that he was somewhat taken aback because he had not expected that his supervisor would expect something definitive and persuasive from him. However, from this experience he realized that an account of the pros and cons of various methods "just gives [the supervisor] more work to do."

Compared to the students, Thomas was more emphatic about the importance of considering one's audience in writing. "Audience is absolutely, absolutely fundamental in your writing," he said. Workplace readers expect writing to be concise, precise, logical, visual, and conclusive, and more specific criteria need to be applied for different audiences. Thomas said that because readers generally devote only a few minutes of their attention to any one document, writers have to learn how to direct readers' attention to the primary information and leave secondary or supporting information in appendices. And capturing the attention of one's audiences is also crucial:

> Once you've grabbed their attention and convinced them that what they are reading is worthwhile, the rest of it is pretty much down hill from there. And now all you have to do is prove to them that your logic is sound and what you are trying to persuade them to do actually makes sense; most people out here have no reason but to accept what you are going to say. The key is getting them to recognize the importance of it [...]

Thomas also underscored the importance of writing for intended and unintended audiences. Occasionally, the immediate audience for a document is clearly delineated, but he may not always know to whom his documents will be forwarded. Through experience, he has learned to try to imagine other potential audiences. "I have sent [meeting minutes] out to people and the next thing [...] people from our corporate office [are] calling me asking me about these meeting minutes. [I'm thinking,] 'Oh, crap, you weren't supposed to see those. Somebody just asked me for those and I quickly forwarded it to them.'" The same has happened with his forwarded emails, he said.

Relative to the students, Nathaniel also placed greater emphasis on the importance of understanding one's audience. When asked to describe the most significant writing issues he has learned about since he finished college, he noted the issue of audience, which is a vital consideration in workplace writing because

> there are certain things somebody is going to want to hear, so you include that; other things that they are not going want to hear, so either you exclude it or if you can't [...] for [...] professional reasons [...] you kind of modify it to sound better than it is, or alter its presentation to make it appear better—not altogether a lie, just fashion it in a different way [...]

Respondent One: "This is a slippery slope! In mineral property feasibility and evaluations studies, you damn well better tell it like it is. As the preparer of this type of document, you are liable for what you portray. If all the readers interpret your writing as conveying some things that are not really quite as good as you portrayed them, then guess what; after the facts are revealed, a jury may very well convict you of a libelous act and there goes your house. The same is true of simply not reporting something that is negative [...]. This brings up a good point: every SD course should contain at least one lesson on Ethics and Liabilities related to performing feasibility and evaluation type of work. The student needs to know, if he is working as a consultant after graduation on this type of work, he is indeed liable and he may indeed be betting his house on the report's accuracy."

He also noted a generational difference in workplace audiences, saying that "the people who are intelligent, who are actually the people [who] are the top and run things and make things happen, I think [writing] is important to them, especially from the 'older school.' [Unlike younger professionals], the previous generations had a lot more appreciation for writing and [...] how things were suppose to be constructed." He said he is generally meticulous in his writing, but even more so when he is writing to someone over 50 and in a position of power.

Unlike the alumni, faculty differed with one another in the degree of importance they placed on audience considerations. On the one hand, Rikard downplayed their importance. In industrial settings, the role of persuasion is muted by strong audience expectations for quantitative evidence that addresses the bottom line. In contrast, his faculty colleague placed a greater degree of emphasis on audience matters. According to Illan, upper management and other workplace audiences can be persuaded to adopt or reject your recommendations. Compared to academic writing, he said, industry memos often have a much more overt persuasive purpose since writers are writing to elicit action from their audience based on the writer's recommendation and supporting evidence; writing industry memos required him to clearly frame his purpose "so that you can get them to do what you want them to do." He did note that when writing to other people with technical backgrounds, persuasion is often in the hypotheses and plays a less explicit role.

Like the alumni, both clients placed significant emphasis on the importance of audience for effective written communication. When asked to list the most important things he had learned about writing since he started his professional career, the first aspect Byron stated was to consider one's audience. He underscored the highly time-pressured environment in which workplace writing occurs, and noted that ideas are less likely to travel from concept to reality if they are not presented in a way that readers can quickly and effectively understand. He provided a few examples of ways in which workplace writers can better meet audience needs by providing sufficient but not excessive amounts of information. Writers can, for example, direct emails and other correspondence only to those who need the information, and not to general lists. Also, writers can avoid minutia and present readers with rapid access to the main points so those in certain positions can provide input or make decisions based on that information. Overall, more important than flawless grammar and punctuation is the ability to convey main ideas clearly, concisely, and precisely, he said. However, he acknowledged that effective oral and written communication skills are learned, take time to hone, and “very few people are just excellent at [these] when they are 21 years old.”

Like Byron, Ed concurred that audience expectations play an important role in workplace writing, largely because of intense time pressures. He concurred that effective writers consciously or unconsciously internalize audience expectations and know whether to condense or expand particular types of information to fit audience needs. As an example of addressing diverse reader expectations, he contrasted a previous mine manager who requested very little detail in written documents and his current mine manager who requires a great deal more explanation and decision justification. Referring to the job of communicating effectively, Ed said that knowing audience expectations increases one’s chances of “getting it right the first time.” Audience considerations are also important because people with hidden agendas “sometimes would like you to write things to kind of give their ideas a plug or their overall thinking, but again if you go back to either the historic or documented information [...] that may discredit where they want you to go.” Such subtexts influence the way documents are presented. “As you go to that individual for feedback on a different part of the project, [his hidden agenda] really comes into light because [...] the individual I have to deal with doesn’t really accept the full project and so in a way he’s still trying to kill the other parts of it due to his hidden agendas.”

Respondent One: "[...] Writing is extremely important if you are going to rise through the ranks in industry and there is no question that you must know your audience. As I mentioned before for the SD report, when you have a mixed audience and either because the person is non-technical or you are trying to spare them the time of wading through the technical aspects of your report, put them in an appendices where they can be found if needed."

Persuasion

As noted above, the separation of audience and persuasion issues into two distinct sections here is problematic due to the degree of conceptual overlap when discussing either. Many of the statements above regarding audience also fit into this section on persuasion, and some of the forthcoming comments could appear in the previous section on audience. However, participants also provided some comments primarily about persuasion. Byron noted that apart from informing others, persuasion is the main reason we write, and participants generally ascribed a significant role to persuasion in their writing. If persuasion is important to participants, it is of interest to know what factors persuade mining engineering readers. This discussion will explore participant comments on the influence of money, non-engineers, and reasons for the overall importance of persuasion.

The Bottom Line: Money Matters in Persuasion

As Rikard noted above, persuasion, particularly in industry, is guided largely by financial considerations. In industrial settings, he said, persuasion occurs when writers meet strong audience expectations for quantitative evidence that addresses the bottom line. He noted that "[...] in engineering jobs in managerial judgment, they look at the numbers, which number is smaller, which costs less money. And maybe it is not written as well as the other one, but I will take [the one that costs less]." Michael agreed, noting that after conducting his internship bench height study, the company decided on a particular bench height "primarily because that study showed the cost factor, the figures." He added that the study featured "supporting figures, tables and stuff, to convince [...]. I showed everybody all the different figures; I brought different maps, theoretical hauling simulation [data]." For Michael, among the most persuasive data are those that show cost-effectiveness. "I think a huge part of persuasion in the mining industry is money," he said. For example, when you need new equipment, "you need to persuade the technical manager that that cost is worth it. And you have to convince somebody that you need the money to purchase it."

Respondent One: "I think that Rikard is forgetting that in today's society, safety, environmental issues and sustainable development are issues on management's mind just as much as which cost less. Which solution will keep them out of trouble and in the good graces of the public may be more important than the direct cost."

Ed also noted the importance of the bottom line as a persuasive factor. Because of time and efficiency pressures, cost savings and productivity increases are primary persuasive forces, he said. He mentioned rewriting an expenditure authorization after conducting a study that substantiated his claims, and the "persuasion factor was the increase of the productivity of our truck shovel fleet by using this additional tractor." As might be expected, all of the participants who commented on financial issues acknowledged the persuasive nature of cost factors.

Persuasion and Non-Engineers

In the section above on writing to non-engineering audiences, participants explained that learning to write to non-engineers is important, among other reasons, because decision makers in industry often hail from disciplines other than engineering. For example, Illan indicated that when writing in industry, effective mining engineers need to be able to tailor their writing to people in upper management who do not have engineering degrees or even technical backgrounds. Nathaniel added that persuasion plays a role in situations such as soliciting venture capital and writing introductory letters to persuade non-engineering audiences that you are a highly competent engineer. As Byron pointed out, highly influential audiences in industry might have degrees in anything from marketing or finance to accounting or law—or no degree at all.

Elaboration on Persuasion: A Crescendo

Participant comments varied in their degree of elaboration on the topic of persuasion. Among participants, students had relatively less elaborate comments on persuasion while those in positions of leadership tended to have the most elaborate comments; the latter participants tended to place a correspondingly greater degree of importance on the role of persuasion. This section will describe that crescendo.

Michael's comments on persuasion contained conflicting tensions. He acknowledged the role of persuasion via financial and technical facts and figures, yet the notion of persuasion seemed more obscure when it emanated from his own writing. For instance, while he noted the necessity of persuasion in new expenditure requests and other workplace communication, he indicated that the sample geological feasibility study he brought to the interview was not persuasive in purpose but "purely factual information." He added that the report is "not talking about money or whether we should do anything with the deposit." Yet he also noted that the report is "part of a feasibility study because these geological considerations will impact on these building projects." He provided another example of this tension when he noted that the purpose of the SD final report is both to get a grade from the professor and to provide information to the client, but, he said, it is not persuasive. However, he went on to say that the SD final report would "show that I've done a lot of work and, I think, it's the definitive answer of 'yes, develop this mine or no, do not develop this mine.'" He added that his goal "is to say 'yes, this method will give you a profit or no, it won't. And therefore you should do it or you shouldn't.' And then, my design could be compared to different designs, which might be better or could be worse."

Hugh's comments also indicated a conflicting tension as well as a change over time in the degree of importance he placed on persuasion in workplace writing. He stated that the purpose of the SD final report, which he brought to the interview, was to show his professors what work he had completed. He added, "it's not my place to make conclusions necessarily; [the clients] are the ones who ultimately have to make decisions. I provide the information." He distinguished between conclusions, which definitively describe the best option, and recommendations, which recommend ideas to consider. However, when asked, he also indicated that the purpose of the report was persuasive since the evidence "shows that certain courses of action would be more desirable than others." Beyond the context of SD writing, however, Hugh said the role of persuasion is significant. In workplace writing, persuasion plays a very important role because supervisors prefer concrete, definitive information and recommendations to mere analyses of advantages and disadvantages of various alternatives, as he discovered first-hand in his internship, described above. He noted that "persuasion is very important in all professional dealings, especially writing."

Respondent One: "Maybe I am missing something in the way the SD is taught at [the study site university]. If a mineral property feasibility and evaluation report is put together as a SD, then it is incomplete if it does not contain recommendations as to what the evaluator would recommend from what he found out about the deposit. In industry, many more times than not, the recommendation will be to not move forward on the property. Conclusions, even negative ones must be there. Why else would the study be done. At that point in time when this phase of the project is completed, who knows the property and project better than the person(s) who did the study. Management expects them to make a recommendation!"

Hugh added that he did not think he would encounter in the workplace the kind of persuasive writing he did in his liberal arts courses, which included defending an opinion, analyzing a group of people, and composing policy-oriented papers. "I think my workplace writing will be almost all technical," he noted. However, this view changed. In the two months after he made these comments, Hugh graduated from college and began working for a mining company. After he read through a summary of his interview, he wrote, "I think I didn't give enough credit to persuasion in writing during my interview. Since I've been working all of my writing has involved technical elements and at least 50% of it has used the technical elements to be persuasive."

Respondent One: "This is absolutely not true for those of us who have been involved in hundreds of mineral property evaluation studies. Even when I was involved in mining industrial research projects, and when the new system was ready to be introduced to the mine work force, much persuasive writing had to convince management first and then the first line supervisors that the new system was a better way. Also, going back to my comments on safety, environment and sustainable development, persuasive documents must be written if our industry is to survive."

Although Rikard indicated that financial considerations constitute a major persuasive force in engineering writing, particularly in industry, he also acknowledged that persuasion occurs on both conscious and unconscious levels. Persuasion occurs on a conscious level since mining engineering readers expect writers to clearly convey the "scientific and engineering considerations that [they have] taken into account" to support their recommendations. He said that persuasion may also occur on largely unconscious levels.

Unlike Michael, Hugh, and Rikard, the other participants placed a greater degree of importance on the role of persuasion in engineering writing. For example, when asked to describe the most significant writing issues he has learned about since he finished college, Nathaniel noted the issues of audience and purpose. Specifically, he said he has learned a great deal about how to achieve his rhetorical purpose more efficiently with particular audiences whether it be in soliciting venture capital from financial institutions or in writing introductory letters to persuade others that he is a highly competent engineer. He also indicated that technical knowledge has a particular potential for persuasion. In meetings with non-engineers, he sometimes consciously turns the topic to technical matters:

> [...] even if what I am talking about is borderline nonsense, the more technical I get, your accountants and lawyers become uncomfortable because they don't know what you are talking about. And especially lawyers [...] they will never admit or ask questions [if] they don't know something. They [...] will scurry away from the topic and let you have your way [...]. This is a tactic that I have used repeatedly, and it works very well.

Respondent One: "It doesn't matter if the lawyers understand it or not, persuasive documents must be written for many, many reasons."

As someone whose writing was a major catalyst for being recognized by upper management in industry, which in turn led to promotion, it is perhaps no surprise that Illan spoke decisively about the importance of persuasion. Persuasion plays a significant role in mining engineering because upper management and others can be persuaded to adopt or reject your recommendations, he stated. Compared to academic writing, industry memos often have a much more overt persuasive purpose since writers are writing to elicit action based on the writer's recommendation and supporting evidence; writing industry memos required him to clearly frame his purpose "so that you can get them to do what you want them to do," he said. He noted that he would often take a great deal of time in crafting those memos so they concisely and precisely achieved his purpose.

Ed also commented extensively on the importance of persuasion, which he said plays a significant role in workplace writing "because you try to persuade your audience with the information that you have and what you're trying to get to." Texts are more persuasive when they anticipate and address the major questions readers may have, he said. He also noted that written documents that attempt to be manipulative and that are driven by a "hidden agenda" can sometimes be detected because they often lack sufficient historic substantiation.

Speaking from experience, he noted that sometimes colleagues with hidden agendas "would like you to write things to kind of give their ideas a plug or their overall thinking, but again if you go back to either the historic or documented information that you already have, [...] that may discredit where they want you to go." Such subtexts influence the way documents are presented. Referring to a particularly recent case involving a coworker with a hidden agenda, he noted that "as you go to that individual for feedback on a different part of the project, [his hidden agenda] really comes into light because [...] the individual I have to deal with doesn't really accept the full project and so in a way he's still trying to kill the other parts of it due to his hidden agendas." In that sense, persuasive and other workplace writing reveals "what type of person you are [...and] what kind of thinker you are and how you go through the [problem-solving] processes." He added that people who can persuade others with their writing tend to be more successful in their careers.

Like Ed, Byron indicated that persuasion is one of the most important aspects of writing. His response to an open-ended question on the role of persuasion in written workplace documents was, "Isn't that what writing is all about?" Along with conveying information, persuasion is "the only reason that you write anything," he said. When asked to describe the most important writing issues he had learned since he began his career over two decades ago, he listed audience considerations first, and added, "number two is support with data, and I am not just talking about numbers either. If I have an opinion about a particular direction in the marketplace, and I don't have market research data but I have opinions of customers, that's good data too. Support with data but don't overwhelm." He reiterated that in addition to meeting audience expectations, the features of written documents that most effectively persuade mining engineering readers include a concise summary of the main issues followed by the proposal and suggested solutions, supported by the appropriate technical data, which often appear in an appendix. While Byron placed greater emphasis on the importance of oral communication skills, he also emphasized the importance of writing. "The only way to communicate your ideas and get from line drawings to actual build is to be able to justify what you are doing with the written word. The drawings alone are not understood by senior managers," he said. The inability to effectively persuade readers can negatively influence one's chances of career advancement, he noted.

Thomas indicated that he may be more attuned to the importance of persuasion than a typical mining engineer because his position requires him to facilitate change in processes and in people.

> [...] the value we will see from [our division] in productivity is big—half a million bucks [annually]. But it's the value that we see in the change in culture that can't be valued. It's just immense. That's exactly what the agenda of the project is—through productivity initiatives, through employee involvement, we change the culture to a culture that's willing to change and look for improvement as opposed to one that is resistant to change and wants the status quo.

Persuasion occurs in numerous ways, including straightforward informative updates. "I have got to keep everybody updated because change is simply the hardest thing that you do in mining [...] and the number one reason is because of the lack of communication." Persuasion occurs through both oral and written communication, he said.

> [...] if you really want to be effective in persuasion, they can't know that that's what you're doing. When you get up and do a presentation, that's much more difficult to conceal, but in writing it's much easier. You can persuade someone in writing and lead them to the conclusion that you want them to get, without them ever really know what you are doing.

Concealing or withholding information may make a presentation clearer and more effective because "a good engineer knows when to shut up. You can give people too much information. Then they will start asking questions that you don't have the answers to, but also that have no pertinence to the project." Such sidetracking discussions waste everyone's time, he said. Furthermore, excessive information is also seen as "fluff." Speaking of his general manager, he noted that

> [...] if you are trying to fluff him up with numbers and volume, he's going to see right through it, and recognize you have no idea what you are talking about. So if you are willing to cut to the chase and say, 'Look, this is it. I am being clear about what I am trying to do,' he's happy to recognize that, and then if he wants to know more he will ask.

Since he was hired three years ago, Thomas has learned to make his writing more concise and, therefore, clearer and more persuasive. He said that making writing brief "forces me into removing all the excess verbiage and everything else that I don't need [...]. When you shorten [your writing...], you get the clarity back.'"

Persuasion also occurs through audience-appropriate presentation. "You tell people, 'Well, we would really like to save two tenths of an hour on our overburdened trucks through fueling every shift' [and they might respond,] 'Two tenths of an hour, come on, that is nothing.' 'Yeah, well we think it can save us $150,000 a year' [and they would probably say] 'Oh, well let me jump on board with that project.'" To persuade, writers need to follow a certain sequence, he said. This involves showing readers why an idea is important, providing sound supporting logic and data, and communicating the reasons for rejecting certain alternative solutions. As an example, he noted that "when we are talking to hourly folks, we will actually go into a little bit more detail about some of the alternatives that we didn't recommend." This gives them "some basis to say, 'Okay, I buy that; that makes sense.'"

Researcher Commentary: Rhetorical Issues in Engineering Contexts

Participant comments on rhetorical issues can be examined by looking at participants' current career exigencies, their description of their own identities as writers and engineers, their awareness of the importance of writing to non-engineering audiences, and a continuum of rhetorical awareness.

Current Exigencies

In participants' diverse responses to SD, they tended to value what they perceived to need most in that particular time of their careers, and since participants reside at different stages of their careers, it is no surprise that their values differed. Their responses on workplace writing also reinforce this notion that we often value what we most need at present. For example, although Thomas is now acutely aware of the importance of effective project management characteristics, and in fact has championed their importance both within his own organization and via conversations with Rikard and Illan, those same elements in his SD course were not meaningful enough to be recalled three years later. From the syllabus descriptions and from an interview with Illan prior to this study, it was clear that project management played a role in SD. Both instructors also explicitly mentioned the importance of project management in interviews for this study. So why did Thomas not recognize those elements of project management, and in certain cases even lament the absence of project management components that were actually present in his SD experience?

Certainly many reasons may account for this phenomenon. As a college senior, Thomas did not have a frame of reference in which such skill sets held significant value, even though this changed three years later. Thomas as a college senior did not recognize the same degree of importance in ensuring client satisfaction as he does today in his leadership position within a coal company. His foci then more likely centered on solving the technical aspects of the problem and on rendering satisfaction to the audience that effective students have learned to please from the age of five on up: their teachers. This may also account for some of the diverse conceptions of audience for the SD final report. Only after three years of learning to read the complex needs of industry audiences has Thomas recognized the importance of project management skills, the very same skills Illan was attempting to inculcate by scaffolding progress reports and oral updates across the student-created timeline for their SD projects. Parents or educators reading this might nod knowingly at the notion that people with more life and career experience tend to value skills and abilities that differ from individuals with relatively less life and career experience.

Yet our challenge as parents or educators is not to be parental in the negative sense of the term, but to encourage reflection on current mindsets and their accompanying values as a means of fostering their development and evolution. Arguably, this is exactly what Illan and Rikard intended the mining engineering curriculum and particularly SD to accomplish. In attempting this, however, they encountered one of the educator's most persistent challenges: teaching skills, abilities, and habits of mind that are valued by the very same disciplinary community that apprentice students have not yet come to know through any extended experiential contact. By extension, college students may (or may not) trust faculty when they ask students to perform tasks that are purported to be close approximations of professional practice; although students may recognize intellectually the connection between the task and real practice, they often do not have the *experiential* base that solidifies the importance and utility of those skill sets and abilities. Particularly among undergraduates, this can result in students viewing tasks and challenges as mere academic exercises rather than attempts to develop pivotal career attributes. Research and insights into this process, and how this process may differ with students who return to college after more extended life and career experiences, may shed light on how to meet this persistent challenge more effectively.

Writers' Identities and Engineers' Identities: Diverse Perceptions of Authority

Participant comments on rhetorical issues provide a glimpse into their sense of their identities or selves as writers and as engineers, selves that differ among participants in terms of their degree of perceived authority. Here, the word *self* is used to refer to one's identity and role in a given context to underscore the notion that individuals inhabit multiple selves. For example, Byron has a writer self, an engineer self, a male self, a division president self, as well as a husband self, a father self, and many more.

Like some of the more experienced engineering participants in this study, Ed notes that ideally writer selves and engineering selves are integrated and not separate. He remarked that colleagues with a reputation for clear, logical writing gain respect because workplace writing reveals "what type of person you are [...and] what kind of thinker you are and how you go through the [problem-solving] processes. I think that conveys a lot of information to upper management as far as what type of work you have done." He added, "I know certain people I work with, I am impressed with their ability not only because they can write a document, but the process that they follow in their thinking and logic." Here, Ed is describing writing abilities not as ancillary or external to engineering practice but as integral components.

By contrast, Michael and Hugh, while they recognize, albeit in an abstract rather than profoundly experiential sense, that writing skills are important, they do not tend to describe writing skills as components of their engineering selves. This may be related to the fact that their writer selves are not yet empowered with the same degree of authority or confidence one would expect in more experienced engineers. In fact, Michael and Hugh describe themselves as primarily providers of information and not as engineers whose knowledge and presentation of knowledge has the ability to persuade industry clients or practicing engineers. Compared to other participants, this relatively lesser sense of agency, or authorial power, may stem from a complex combination of factors such as relative inexperience, lack of confidence, real and/or perceived apprentice or novice status, and others.

Ed's comments above contrast sharply with Michael and Hugh's description of their own writer and engineer selves, and Illan's comments do as well. In fact, Illan's testimony of transformation over the course of a few decades—from fear-filled to confident writer—reinforces the notion that one's writer self and engineer self can initially be separate and later conjoin. Illan says that he is adamant about writing *as an important aspect of engineering* largely because of his own transformation. However, this is not the case for all of the study participants. Rikard, for example, to some degree still seems to hold his writer self apart from his engineering self. Clearly, the individual life and career experiences of participants has a profound influence on their notions of the importance of rhetoric in general, and of their perceptions regarding their own writer and engineering selves, including the degree to which those two selves are integrated and complementary.

Writing to Non-Engineers: Awareness as a Function of Experience

Among participants, the degree of awareness about the importance of writing to non-engineers varies considerably and is directly related to experience levels. Michael and Hugh have relatively less elaborate comments about writing to non-engineers. This may stem from inexperience with situations in which such writing was necessary and from academic writing-in-the-discipline experiences in which students are asked only to write to other engineers or technical audiences. Michael acknowledges a struggle common among many engineering students—and writers generally—when he notes that writing involves thinking not like the writer but like the reader. If this process is difficult when communicating technical ideas to technical audiences, one can assume the processes of communicating technical ideas to non-technical audiences is even more difficult.

Participant descriptions about the importance of writing to non-engineering audiences, especially given the lack of commentary on this topic from Michael and Hugh, has pedagogical implications. For example, engineering educators may want to consider (or continue) fostering the expansion of students' rhetorical horizons and their ability to meet multiple audience needs by having students rewrite technical papers or passages for non-engineering audiences. Of course, students may not perceive such well-intentioned assignments as authentic or representative of actual engineering practice, a notion exemplified by Hugh, who thinks the vast majority of his workplace writing will be technical. To augment the credibility of such an assignment, educators should provide examples of actual cases—potentially from their own industry experiences—in which engineers have been called upon to communicate technical concepts to people with non-engineering and/or non-technical backgrounds.

A Continuum of Rhetorical Awareness

Participant comments on rhetoric seem to lie at various points along a continuum of rhetorical awareness, one that seems to begin with a kind of denial. Comments from three participants reveal a tension between denying and acknowledging rhetoric as influential in written engineering communications.

For example, in describing the sample geological feasibility study Michael brought to the interview, he indicated that it was not persuasive in purpose but "purely factual information." Michael added that the report is "not talking about money or whether we should do anything with the deposit." Yet a moment later he noted that the report will have an impact on plans for building projects. Perhaps he did not consider this implicit rather than explicit form of persuasion because he only sees persuasive texts as embodying high stakes recommendations. He may also consider the feasibility study descriptive and not persuasive because he views his own role as fact provider and the readers' role as fact receiver, a notion explored more below.

Michael's notion that his reports contain "purely factual information" suggests that he believes data alone convince engineers to find a recommendation credible. Certainly, data do convince. However, they often need a spokesperson, interpreter, or guide—and even more so as the meaning and implications of the data are ambiguous and/or involve high stakes, a notion foregrounded by Winsor (1996). As further evidence of this notion that data speak for themselves, Michael indicated that the final report in SD would not be persuasive even though he also stated that the SD final report would provide a "definitive answer" regarding whether a mine site should be developed and whether it would be profitable.

Clearly, his notions of persuasion do not include overt recommendations to follow a particular course of action. What, then, constitutes persuasion for Michael? He indicated that persuasion is necessary when a decision involves money or a recommendation, so he clearly acknowledges the existence of and need for rhetoric in some engineering contexts. Yet both his geological feasibility study and his SD final report clearly either involve money, provide a recommendation, or both, and he still considers neither persuasive.

One of the contributing reasons for this contradiction in the case of the SD final report may be a writer rather than reader-centered approach to the text. In recounting the purpose of this final report, he said it was to obtain a grade from the professor primarily and to transfer information to the client secondarily. Another possible contributing factor is that Michael and Hugh are on the cusp between two incompatible conceptions of rhetoric; the first denies that technical professionals are influenced by rhetorical considerations while the second begins to acknowledge how issues of audience and persuasion carry some influence. That is, their comments suggest that Michael and Hugh simultaneously deny and acknowledge the existence of rhetorical influences. Intriguingly, Michael clearly acknowledges such influences in many cases in which he is not the document's author, yet denies them when he is. Among other factors, this split viewpoint probably stems from a minimized authorial identity consonant with their real or perceived apprentice status in the profession and with their views on the roles of readers and writers.

The idea that data speak for themselves and do not need an author to provide interpretation of the meaning and implications of data, which is present in Michael and Hugh's statements, may be one of the most dangerous rhetorical blind spots in engineering. One aspect of the 1986 Challenger disaster can illustrate this point (Winsor, 1996). Winsor notes that the belief that technical data speak for themselves contributed to the space shuttle disaster. Engineers at Morton Thiokol, the subcontractor that made the solid rocket boosters for NASA, had lab data indicating that the joint that sealed the O-ring—the one that eventually failed—was sensitive to cold temperatures. While they conveyed this data to NASA, the Morton Thiokol engineers assumed that by simply sending data to their managers, the managers would interpret the data just as the Morton Thiokol engineers did. However, the engineers at NASA saw the track record of successful launches as evidence of the joint's safety, and deemed these data more relevant than the lab data. Although multiple other contextual factors also led the NASA engineers to this interpretation, Winsor (1996) points out that

> the relevance of different data was unclear, and the meaning of any of the data required interpretation. The existence of data alone was insufficient to create knowledge. People needed to persuade one another of the meaning of the data they had, but they failed to do so partly because they did not seem to know such persuasion was necessary. (p. 3)

Winsor (1996) states the implications of denying rhetorical influences by noting that

> because cultural beliefs about technical knowledge and the actual needs of engineering practice conflict, it is possible that the effectiveness of engineers is diminished and that the professional development of young engineers is needlessly retarded. Such consequences are not only frustrating for engineers

> but also potentially harmful to society at large because they can result in inferior and even dangerous products. (p. 2)

Winsor's research suggests that a student's engineering discipline implicitly teaches him or her either that rhetoric is irrelevant or that the effective use of rhetoric involves the denial that one is using rhetoric. Acknowledging rhetoric formally would, among other things, fissure the breastplate of scientific objectivity and potentially detract from the focus on the data as persuasive force. However, as Winsor's study and this study suggest, disciplinary practice more explicitly calls for writers to act as spokespersons or guides for the data they have analyzed, in part because they are often the most familiar with the data and thus their perspective is valuable, especially regarding the *meaning* and *implications* of the data.

Whereas Michael seems to deny rhetorical influences when he is the author and acknowledge them when he is not, Hugh seems to deny rhetoric in most academic contexts and acknowledge them more readily in industrial contexts. On the one hand, Hugh describes his audience for the final report as faculty and not as the client because the client already knows much of the contents of the report and may only use it as a reference document. By contrast, he says a report truly intended for the client would be much more condensed and would contain more procedural detail and fewer conclusions since he describes his role as nothing more than an information provider, at a considerable distance from the decision-making potential that he says rests exclusively with the client. While in this instance he denies his persuasive role, in another he recognizes it. Recounting an experience on his internship in which he was asked to analyze an alternative haul route and state the advantages and disadvantages of various routes, he noted that his supervisor clearly expected something definitive and persuasive because an account of the pros and cons of various methods "just gives him more work to do."

This tension surfaces elsewhere. Hugh also indicated that the purpose of the final report was to show his professors what work he had completed. However, when asked *directly*, he said that the purpose was persuasive since the evidence "shows that certain courses of action would be more desirable than others." He then distinguished between conclusions, which definitively describe the best option, and recommendations, which recommend ideas to consider. This distinction may be his way of making sense of the rhetorical tensions he is currently experiencing and of again attempting to maintain distance from any semblance of rhetorical influence. Yet at another point in the interview, he underscored the importance of persuasion on the job, particularly in workplace writing.

Clearly, Michael and Hugh's statements suggest a tension between the writer's role as mere conveyer of data vs. persuader of audiences. As novice or apprentice members of the profession, Michael and Hugh may also deny rhetorical influences because of their identities as writers, which are not as likely to be as self-assured as more experienced engineers. Evidence of Hugh's growing awareness of the role of rhetoric also appears in his confirmation, made two months after starting his first post-baccalaureate job, that the interview summary was accurate. To that confirmation, he added that persuasion plays a more significant role in his workplace writing than he had anticipated.

However, the simultaneous denial and acknowledgement of rhetorical influences was not unique to the youngest participants in this study. Traces of this tension also appeared in Rikard's comments. For example, in terms of the SD final report, Rikard indicated that audience plays little to no role in SD writing. Yet other participant comments regarding the primary and secondary audiences for the SD final report reveal diverse interpretations and disagreement about the reports' intended audience(s). While writing to other engineers did not present important audience issues for Rikard, he also stated that conveying ideas to non-engineering audiences was among the engineer's greatest challenges.

Furthermore, Rikard indicated that especially in industrial settings, the role of persuasion is largely muted by strong audience expectations for objective, quantitative evidence that addresses the bottom line. Yet Rikard also acknowledged the importance of rhetorical influences. Toward the end of the interview, he said that persuasion can occur on a conscious level since mining engineering readers expect writers to clearly convey the "scientific and engineering considerations that [they have] taken into account" to support their recommendations. However, he indicated it may more commonly operate on a less conscious level:

> In terms of clarity, in terms of intelligent definition, [persuasion] definitely has a major role. Because I do know […] there is a great frustration [as] a reader [in determining] what the heck [the writer] wants to tell me […]. I do not want to degrade the importance of the clarity, the style of the report in accepting [the writer's technical ideas]. I think it has a major, major influence, maybe unconsciously […]. We do not want to be [subjectively influenced]. We want to be very objective but probably unconsciously […] the right, written clarity and style and everything [is] probably—maybe [in] an unconscious way—a major part of engineering.

Given the tentative and cautious tone—evidenced by words such as "maybe" and "probably"—it seems Rikard is wrestling with the same clash Winsor's research identified; that is, a clash between a disciplinary ideology that values objectivity on the one hand and on the other an engineering praxis that acknowledges the role non-objective factors play in influencing what counts as knowledge, what and how decisions are made, and more. Again, acknowledging the role of rhetorical influences in engineering may seem to poke holes in the armor of idealized scientific objectivity, a core disciplinary value. This may help to explain why, as Winsor has noted, in engineering contexts "effective rhetoric involves the denial that one is using rhetoric" (1996, p. 7). Why Rikard holds a viewpoint similar to Michael and Hugh, despite his relatively greater experience, is somewhat unclear, although it may be linked to his experiences as a writer and his writer identity.

The character of participant comments on rhetorical issues differed between Michael, Hugh, Rikard and the other five participants. Specifically, they differ in the degree of importance and emphasis given to the topics of audience and persuasion. Correspondingly, the participants differ in the degree of elaboration in their comments on those topics. Beyond these contrasts, other differences exist in the ways in which the other five participants described audience and persuasion. These differences become apparent in examining the comments of Nathaniel, Thomas, Illan, Ed, and Byron.

Three years have passed since Nathaniel and Thomas were SD students, yet their descriptions of audience and persuasion differ markedly from Michael and Hugh. It should be noted that while Nathaniel and Thomas have three more years of industry experience than Michael and

Hugh, Hugh and both alumni are only one chronological year apart because Hugh took two years off in college for missionary work, and all four entered college immediately after high school. This suggests that chronological maturation alone does not necessarily foster rhetorical awareness; rather, it suggests that certain types and durations of workplace experiences as practicing engineers may be pivotal in developing such awareness, although such a conclusion is certainly tentative given the sample size and number of other potential variables involved.

Relative to Michael, Hugh, and Rikard, Nathaniel's comments reveal a fairly sophisticated understanding of why professional writing needs to be tailored to the needs, expectations, and knowledge levels of various audiences, including non-engineering audiences. Perhaps the most overt acknowledgement that persuasion is important for engineers came in his discussion of business meetings with non-engineers, in which Nathaniel sometimes consciously turns the topic to technical matters to sway audiences such as accountants and lawyers.

Granted, Nathaniel's entrepreneurial experiences are somewhat unique among participants. At one point, he said his professional dealings require him to be like an actor in Hollywood, indicating an awareness of the needs of diverse audiences and underscoring his need to be able to persuade others in order to do many common workplace activities—secure competitive bids, raise venture capital, and convince future business partners or employers of his professional competence. A certain amount of "selling" oneself occurs in all of those, so it should come as no surprise that he accentuates the power of persuasion. The word *power* is used here specifically because it encompasses the positive and influential as well as negative and manipulative potential of persuasion, as well as points in between.

Perhaps the fairly sophisticated rhetorical awareness among some participants in this study stems from the multi and interdisciplinary nature of mining engineering. Also, rhetorical awareness may be commonplace among practicing engineers generally, as one historian of writing has suggested (Russell, 1991).

> The engineer must not only speak the language of, say, the physicist, but also, in certain instances, the language of the industrial manager, the lawyer, or the foreman on a construction site. And the complexities of playing this intermediate role are vitally apparent in the written products of the engineer, the myriad letters, reports, contracts, specifications, and proposals addressed to audiences with varying interests and technical backgrounds. Unlike the physicist, whose professional writing is almost always addressed to a community or, more often, a subcommunity of other physicists, the engineer in 'real life' is much more likely to face complex rhetorical problems in translating information from one community to another. Thus, writing cannot as easily remain transparent. (p. 120)

Like Nathaniel, Thomas's statements on audience and persuasion were also more elaborate than Michael, Hugh, and Rikard. Because Thomas's comments here resemble Byron's comments and in some respects depict the upper end of the continuum of rhetorical awareness, I will first look at the statements of Illan and Ed.

Compared to Michael, Hugh, and Rikard, statements by Illan suggest a relatively elaborate awareness of rhetorical issues. Specifically, Illan's comments reveal a more detailed understanding of the various needs of engineering and non-engineering (or non-technical) audiences, an understanding that likely stems from reflections on his own career experiences. He also drew from these career experiences when he stated that persuasion plays a significant role in mining engineering, since upper management and others in industry can be persuaded to adopt or reject one's recommendations. Compared to academic writing, he said industry memos often have a much more overt persuasive purpose since writers are writing to elicit action based on the writer's recommendation and supporting evidence. Unlike the SD students, he also foregrounded the role of persuasion in the SD final report, which he sees is designed to persuade the client, the primary audience, and the instructor, the secondary audience.

However, Illan noted that students tend to make those SD final report recommendations in a timid or non-forceful manner. He qualified this statement by adding that the student-client relationship also affects the degree of strength in their recommendation; if a student had spent the previous summer working for the client and knows that client well, the recommendations are put forth with greater confidence. In saying this, Illan explicitly acknowledges that knowledge of the people and history of an organization can change the way engineering writers approach acts of persuasion. This highlights why context matters and how writing is situated not in a vacuum but in a particular time and place that can influence writers' rhetorical choices in complex ways.

Like Nathaniel and Illan, Ed accentuated the importance of both audience and persuasion. After roughly 17 years as a practicing engineer, Ed concurred with many other participants in noting both the challenge and importance of knowing how to convey ideas to non-technical or non-engineering coworkers. He also portrayed the ability to persuade audiences as crucial to the achievement of a writer's purpose and thus to success in the profession. He highlighted the importance of anticipating and addressing audience questions or concerns by providing relevant background information. His comments also demonstrate a fairly sophisticated level of rhetorical awareness in noting that writing can unveil self-interest and aspects of identity. He said that written documents that attempt to be manipulative and that are driven by a "hidden agenda" can sometimes be detected because they often lack sufficient historic or other substantiation. He also said that persuasive and other workplace writing reveals aspects of one's identity as well as thinking and problem-solving approaches, as he noted that writing renders clear the quality of one's thinking and logic. In that regard, both Illan and Ed suggest that one's writer identity is not ancillary but integral to one's identity as an engineer. That is, while the SD students have a more compartmentalized view of writing as a skill that may be a positive addition to an engineer's career, other, relatively more experienced participants tend to hold a more holistic view in which writing is integral to being an effective, successful engineer.

Thomas and Byron both voiced this viewpoint, among others. Like most participants in this study, Thomas and Byron underscored the importance of understanding how to persuade diverse audiences, but to a greater degree than most participants. They had highly elaborate and unequivocal comments about the importance of audience and persuasion. Among other possible explanations, it is certainly no coincidence that both Thomas and Byron hold leadership roles in which their ability to effect change is vital to their respective organizations and to their own respective careers.

Thomas described himself as a change agent in charge of spearheading improvement initiatives and changing the mentality or culture of people within his organization, so it is perhaps not surprising that he had reflected at length on and was emphatic about the importance of rhetorical influences. He indicated that he may be more attuned to the importance of persuasion than a typical mining engineer because his position requires him to facilitate change in processes and in people.

Thomas's comments about audience and persuasion were generally quite elaborate. For example, he described subtle aspects of indirect and unintended audiences, such as those to whom emails, meeting minutes, or other documents are forwarded. He also had much to say about persuading technical and non-technical colleagues, as well as how to effectively meet the visual or non-visual thinking styles and educational backgrounds of those respective audiences. Since these comments are detailed elsewhere, they are mentioned only in passing here.

According to Thomas, persuasion occurs through a variety of means, from overt and explicit to more subtle. In terms of explicit description, he noted that he provides regular project updates to coworkers to facilitate organizational change. He strongly implied that informed coworkers are more likely to be persuaded than ones holding various misinformation and misconceptions. At the same time, he also acknowledged that persuasion occurs through less explicit means, as the chapter epigraph suggests. His recognition that people can be persuaded through writing that conceals or withholds information has important workplace and ethical implications. Thomas notes that withholding information is not necessarily manipulative, but may actually make a presentation clearer and more effective because excessive information can sidetrack the focus of a discussion toward trivial or irrelevant issues. Such discussions waste time, he said, and diminish the persuasiveness of oral or written presentations.

Like many participants in this study, Thomas commented on how people in the mining industry tend to prefer no-nonsense, straightforward discourse. This value on the clear, concise, and precise, while it demands greater clarity, concision, and precision, also leaves audiences more potentially vulnerable to manipulation and more in greater need of trust for the writer(s) or speaker(s). Why trust is needed in highly quantitative fields may not be apparent at first; most members of the general public do not realize the degree to which quantitative data can be manipulated to conform to particular ends. Had a survey been conducted concerning the need for ethical accounting practices before the Enron, WorldCom, and other corporate scandals, most Americans would have considered ethics largely irrelevant to a field that seems to primarily tabulate and report quantitative facts. Americans now understand more about the need for ethics in quantitative fields. Of course mining engineers, having more exposure to and experience with quantitative data and its various visual representations, probably have developed more precise ways of detecting concealed or withheld data. At the same time, unless inaccuracies or concealed data can be ferreted out quickly, time pressures will make it necessary to trust the accuracy of the data and will prevent extensive searches through supporting data. In that sense, experience and the ability to rapidly detect pertinent (as opposed to irrelevant) concealed, withheld, distorted, or inaccurate data provides value to a company. Because mining engineers depend on quantitative data for safety, legal, and other reasons, the ability to trust coworkers becomes even more important. It is surely no coincidence that in its *Code of Ethics for Engineers,* the National Society of Professional Engineers stipulates that engineers shall "avoid deceptive acts" and "be guided in all their relations by the highest standards of honesty and integrity." This code indicates that one of their specific professional obligations is to "acknowledge their errors and ... not distort or alter the facts" (2003).

Thomas remarked on his mentors' ability to detect embellished data, noting that they will "see right through" fluff and recognize that it may be masking ignorance or deception. But insufficient, rather than excessive, information can also hold persuasive power, possibly via ethical or unethical means, especially since time pressures often work against highly complex issue clarification. Both Ed and Thomas have accentuated rhetorical aspects of engineering practice that were not part of the SD students' realm of rhetorical awareness, and mentioned only tangentially by Rikard. Specifically, they acknowledge that data are often marshaled to favor a particular interpretation via strategic data omission and selection. Furthermore, the way in which Thomas describes his rhetorical awareness is not separate from his identity as an engineer. Rather, his rhetorical knowledge is central to his success as an engineer.

As the division president of a Standard and Poor's 500™ corporation, Byron was also emphatic about issues of audience and persuasion, and like Thomas also provided such comments in the context of descriptions about his role as an agent of influence and change. When asked to list the most important writing issues he had learned since he started his professional career over 20 years ago, the first one he listed was to consider one's audience.

He stressed the importance of being able to communicate effectively to everyone from the hourly employees who may not have a high school education all the way up to senior management. He was equally emphatic about the importance of persuasion. For Byron, along with conveying information, persuasion is the principal purpose for workplace writing.

Although to a more explicit degree than Thomas, Byron's comments about audience and persuasion were also couched within statements of effectiveness as a professional engineer and not as a "writer," a skill the SD students did not seem to describe as integral to engineering practice. For example, Byron said, "Without [an] engineer being able to communicate to a diverse group …their ideas would not go beyond the lines of a piece of paper." He added that failure to consider audience expectations can bore, confuse, and/or annoy one's readers, reducing the engineer's effectiveness in seeing his or her ideas come to fruition. After Byron acknowledged that engineers have a predilection for doing hands-on technical work and for avoiding writing, he cautioned that engineers should not use their learning preferences to serve as an excuse for not improving themselves as engineers: "I think if you ask them to write things down, they are better engineers."

His comments on audience also show how he values writing that saves readers' time. For example, he said that emails are misdirected and inappropriate when distributed to those who do not need that information. He also values the ability to summarize appropriately so his time is not wasted on minutia, and so he can quickly access the main points to help him provide input or make decisions. As noted in Chapter 7, this suggests that values play a significant role in all persuasive communication because we are most persuaded by what we most value. If part of our value system includes time as money, documents that are written in a way that save the reader time are more valuable and thus more persuasive. Certainly, however, brevity and precision do not trump content; a concise, precise document about an unworkable idea is still relatively less valuable. However, effective writing as he defines it plays a role in persuasion.

Overall, this level of emphasis and awareness on rhetorical concerns may be uncommon among young engineers (Thomas most likely being somewhat anomalous) and much more common among upper management because they often have a greater depth of experience in seeing what produces change and what makes an organization run. Also, their success in their role in the organization depends largely on their ability to influence people, so they have every reason to be in tune with, among other things, writing as an informative and persuasive force.

This continuum of viewpoints on the importance and role of rhetoric among participants is summarized in Table 8.1. Participants vary in at least six ways, including the degree of importance they place on rhetorical considerations such as audience and persuasion in profession communication, in their views on the role of objectivity, in their career stages, in their views on the roles of writers and readers as well as of writer identity. Below I have also listed the participants from this study who seem to embody some of the characteristics at various points along the continuum.

Table 8.1 Rhetorical Awareness Continuum

Characteristics	Stage 1	Stage 2	Stage 3	Stage 4
Importance of Rhetoric in Professional Communication	Denial of the relevance or importance of rhetoric	On the cusp between denial and acknowledgement	Overt acknowledgement of the importance of rhetoric	Like stage 3 but with greater emphasis on rhetoric
Role of Objectivity	Objectivity is paramount to good science/ engineering	Objectivity is important for obtaining valid results	Objectivity is an ideal to strive towards; other factors influence human decisions	Objectivity is an ideal but non-objective factors influence human decisions
Career Stage	Early undergraduates	Early-Late undergraduates	Post-undergraduates	Post-undergraduates
Role of Writers	Data conveyers	Data conveyers and data guides	Data providers & spokespersons	Data spokespersons & providers
Role of Readers	Data recipients	Data recipients and interpreters	Primarily data interpreters	Primarily data interpreters
Writer Identity	Writer identity is irrelevant; data persuades, so a spokesperson is unnecessary	Writer identity is minimized, seen as novice, yet sometimes writers need to persuade readers	Workplace exigencies demand a keen awareness of audience and persuasion	Confident, effective engineers know how to marshal data to persuade audiences
Participants who embody some of above characteristics	N/A	Michael, Hugh	Illan, Nathaniel, Ed $\boxed{\text{Rikard}}$	Thomas, Byron
Supporting Research	Winsor (1996), Mathison (2000)	Winsor (1996), this study	This study	This study

The first and part of the second stage are drawn primarily from research by Winsor, who in a longitudinal study evaluated engineering students' conceptions of rhetoric from their first year in college through their fifth and final year of an academic-industry partnership program; students attended the General Motors Institute (now Kettering University), in which their typically five-year undergraduate engineering degree program involved alternating between academic work and six months of work per annum with one of several hundred potential corporate employers (Winsor, 1996). This learning approach allowed students to integrate work with school experiences and vice versa. Two participants were manufacturing engineers while the other two were mechanical engineers, and all were 18 or 19 years old when the study began. She found that the early undergraduate students generally denied the existence of important rhetorical influences in engineering communications, yet that changes in participants were seen over the course of their five-year program, and one of the participants more fully acknowledged a rhetorical view of knowledge. Table 8.1 merits brief explanation of each of the six major points.

Importance of Rhetoric

Although no participants in this study display a complete denial of rhetoric, Michael and Hugh do appear to be on the cusp between denial and acknowledgement, while Rikard manifests traces of denial combined with a perspective in which the importance of rhetoric is overtly acknowledged. The remaining five participants all acknowledge the role of rhetoric, and Thomas and Byron accentuate the importance of rhetoric in facilitating organizational change.

Role of Objectivity

Participant perspectives on the role of objectivity in contexts in which engineering writing occurs vary. Michael and Hugh see objectivity as a core disciplinary value and necessary for effective engineering results while other participants, in varying degrees, also acknowledge non-objective influences on human decisions.

Career Stage

Participant positions on the rhetorical awareness continuum generally correspond directly with their career stages. One might expect one's position to match one's number of years in the profession, but this is not always the case. Thomas and Rikard are at points that do not correspond directly with the number of years in their respective careers. This is likely due to multiple factors, including their organizational roles, experiences as writers, writer identities, and others.

Role of Writers

Participants vary in views that range from writers as primarily data conveyers and secondarily data guides to primarily data spokespersons. As noted below, these views are related to perspectives on the importance of rhetoric, the role of objectivity, and the role of readers and of writer identities.

Role of Readers

Perspectives on reader roles vary from emphasis on readers as mere data recipients to readers as data interpreters; that is, from readers who play a relatively passive role to ones playing relatively more active roles.

Writer Identity

Here we see a movement from conceptions of one's identity as a writer as unimportant, to novice and apprentice, all the way to confident change agent. If one believes in objectivity and the notion that data speak for themselves, rhetoric becomes less relevant, writers are mere data conveyers, readers only receive data, and the writers' identities become largely irrelevant. On the other end of the continuum, data are still important but non-objective, persuasive factors are acknowledged in deciding what counts as valid knowledge. In this latter view, rhetoric matters, effective writers guide readers to particular knowledge conclusions via the skillful marshalling of data, and readers interpret data judiciously.

Implications for Practice

Writing and rhetoric faculty who work with engineers may see these findings as a calling of sorts, perhaps even fodder for required courses in rhetoric for engineers. While I do think instruction in rhetoric does and will continue to play important roles in writing and writing-intensive engineering courses, I would add that students in the second stage would probably consider such instruction a waste of time unless their mindset begins to shift. Facilitating such a shift may require that students have ample exposure to actual workplace case studies if they are to see the applicability of rhetoric in meaningful and memorable contexts.

However, embedding instruction on the importance of rhetorical influences within writing-intensive engineering courses, and especially design courses, has a particularly strong pedagogical foundation. Design courses lend themselves readily to writing and to open-ended problem solving in which higher-order thinking is already expected. Also, engineering students tend to put more trust in their industry-trained engineering professors than in writing faculty. This reinforces the importance of collaboration between writing/rhetoric scholars and engineering faculty.

Assumptions about what students assume and should already know before they enter a particular course guide course design, and SD is no exception. However, when those assumptions are inaccurate, instructors need to adjust their assumptions and the course design and content. In this SD course, both instructors' understandings about the intended audience and purpose of the final report were not in concert with students' understandings or assumptions about that report's audience and purpose. More explicit discussion about the reasons behind faculty and student assumptions regarding the final report's audience and purpose should be incorporated in at least one of the few whole-class meetings. This discussion should also include client understandings; students could, for example, discuss audience and purpose issues with the client via a Letter of Understanding, a common engineering genre in which a consultant writes to the client to ensure both share the same understandings about the purpose, scope, and deliverables of the project. The class could discuss the contents and tone of documents intended solely for the client, the instructor, and for both as a way of better comprehending the needs and expectations of these audiences. To some SD instructors, this idea may seem tangential to the purposes of SD. Yet it mirrors common engineering practice and creates clearer expectations. A related example illustrates precisely why such discussion can be valuable. When Art Young, the director of a writing program at a US university, received a call from a chemistry professor on his campus, Young was initially at a loss to explain why a former student had earned a B in his course, yet performed poorly in a written report for her chemistry professor. Young arranged a meeting with his former student, his colleague, and himself; the trio discovered that the chemistry professor had assumed that standards for effective and clear writing would apply to reports that students turned in, so he did not feel the need to state these in his assignment criteria. Upon not seeing such standards, the student continued to assume that only English professors cared about grammar and document surface features and scientists were only interested in the scientific content of a student-authored report (Young, 1999). Again, this example underscores how assumptions can guide diverse perceptions that need to be clarified through discussion or some form of communication.

References

Engineers, N. S. o. P. (2003). *Code of Ethics for Engineers*. Retrieved July 30, 2003, from http://www.nspe.org/ethics/eh1-code.asp

Mathison, M. (2000). "I don't have to argue my design--the visual speaks for itself": A case study of mediated activity in an introductory mechanical engineering course. In S. Michell & R. Andrews (Eds.), *Learning to argue in higher education* (pp. 74-84). Portsmouth, NH: Boynton/Cook.

Russell, D. R. (1991). Writing and the idea of utility. In *Writing in the academic disciplines, 1870-1990: A curricular history*. Carbondale, IL: Southern Illinois University Press.

Winsor, D. A. (1996). Do Engineers Use Rhetoric? In *Writing Like an Engineer: A Rhetorical Education* (pp. 1-18). Mahwah, NJ: Lawrence Erlbaum Associates.

Young, A. (1999). *Teaching Writing Across the Curriculum* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

CHAPTER 9: WRITING AND THINKING

"[...engineers would] rather cut right to the point of the graph which they really understand than write a whole page that someone has to read through. I think a stereotypical engineer kind of thinks without writing."

--Michael

"When the information that is contained in charts and graphs [is] relationship oriented, to write that out is so inefficient [...]. When you are talking about engineering disciplines and not using graphs and charts, that's completely foreign to an engineer."

--Byron

Embedded within some of the participants' comments regarding SD, socialization, workplace writing, and the rhetorical issues of audience and persuasion is the notion that the act of writing fosters thinking. As described below, participants varied in the degree to which they elaborated on the cognitive benefits of writing as well as on the interactions between visual thinking and textual thinking.

Cognitive Benefits of Writing

Rikard addressed relatively static knowledge, the foundational knowledge on which engineering builds, as well as dynamic knowledge, which is always launching a field into new terrain. He compared static and dynamic forms of knowledge to a building in which the solid, static foundation is constituted by the basic sciences, mathematics, physics, chemistry, and social science, and everything above that is dynamic, continuously changing, as is specific professional knowledge. For Rikard, SD is fostering higher-order thinking in students by creating an opportunity for them to apply prior knowledge (primarily the "tools" learned in previous courses) and to expand that knowledge through new challenges, ones they've never seen in a textbook. In short, "they got a good core from us, then [through SD] they have a good [...] chance to extend," he said. However, Rikard was not sure whether SD students were consciously using writing to foster higher-order thinking or to improve their project value. Rather, he said, "I think that how they use writing is just simple—that's their communication tool."

Hugh said that the writing he did in SD did not foster cognitive growth. Rather, it served as a tool to, for example, obtain additional technical viewpoints via email from the instructor and client. However, he did indicate that the act of writing generally has helped him better learn technical content. He said

> [...] when you start to organize something on paper, then it helps organize things in your mind as well. You start to understand what's going on, especially instead of just reading something; if you start to write about it, then I think it starts to make sense. And you want to be able to write down things that make sense to you and not just what you've heard elsewhere [...] that practice of trying to organize things on paper really helps you understand things.

Expanding on Hugh's notions of the cognitive benefits of writing, Nathaniel indicated that the act of writing increases comprehension and retention and that he has used this learning strategy to learn and remember words and concepts on many occasions. The act of writing is a learning tool because effective writing requires some research and organization of thoughts, he noted.

Michael described a vast variety of cognitive benefits, including ones other participants did not mention. He said that "it takes thought to write well. [...] I kind of see it as a game almost sometimes, writing. You know what you want to say. Sometimes you've just got to figure out the right way to say it." He described writing as a game because "you have a lot of technical stuff to remember. Where [...] you put the commas, when you use it, when you don't, when do I use this word, why do I use that. I think kind of reasoning through when you use certain things, it helps you think differently. And I think also it helps you organize your own thoughts." Organizing one's thoughts involves putting them in a logical, linear order, he said. This might be difficult because he noted that many engineers think in terms of graphs, charts, maps and other visual or technical media. He added,

> I think sometimes when you're doing technical type things, you kind of start doing many steps at once; you might work on one for a while, jump to another task, [then] jump to another task [...]. And to sit down and write about it, you kind of think more logically—explain to another person what you did and why you did it—in a more logical fashion [...]. Writing, I think, has to be really structured [...]. So I think structure in writing can help you keep it straight in your head if you don't have it straight already.

Michael gave specific examples of the cognitive benefits he has reaped from writing. For instance, he described a recent team design report that was written collaboratively, which helped all team members see the project more holistically. "I think us sitting down together and writing that [report], everybody knew what happened. Even though we did different aspects of the project, everybody sat down and [...] looked back [...] on that. I guess I'm comfortable with that because I see the whole picture here. The teammates are helpful; what they did had to mesh with what I did. The big picture." He also described how the act of writing his SD progress memos helped put him at ease because he would realize what he had accomplished and would clarify what he needed to do next. In that case, writing was a relief. He reiterated that the act of writing something down enables engineers "to see the whole picture rather than individual steps."

Beyond providing that holistic perspective, Michael added that the act of writing has also served to help him better understand technical content, saying that writing solidifies his understanding and increases retention and comprehension because he is a visual learner. "I think visually; I kind of picture stuff, so by writing it my own way, I can remember better than remembering when somebody else wrote it. With an equation, I write the equation down. I can remember what it looks like so I can write it in the future. The same way with the content; [...I] keep it more straight if I write it down."

Illan also commented on how writing shapes thinking. Referring to largely static knowledge, such as certain formulae and scientific laws and principles, and dynamic knowledge, which is always changing and launching a field into new terrain, he noted that effective writers

> [...] are able to separate what the static knowledge is and [are] able to present that in a clear manner and then add the more dynamic in the topic. In the background [section of the report] you can clearly see that they understand the static knowledge. They feel comfortable with it when they present the whole report within the context of the static knowledge.

He also noted that students who go beyond the most familiar way of solving problems and explore new tools will be "more successful in life than those who just do the steps that somebody showed them." He said that he used writing to help him study for exams because writing out information was helpful. However, he stressed, that would not work if you fear writing. According to Illan, what may keep many students from improving their writing and thinking is a fear of writing. He indicated that when he was in middle school, he was afraid to even write a post-card, and "if [students] are feeling uncomfortable about writing, they hinder their higher-order thinking skills." Also, he described a fear of writing as a kind of disability; students "need to be very clever higher-order thinkers if they have this handicap," he said. Overall, he thinks that the act of writing helps engineers organize their thoughts, get the work done, and justify their analyses for their clients.

Ed also described ways in which the act of writing facilitates cognitive growth. One of his comments echoes Michael's thoughts about the holistic perspective that emerges from writing; Ed said he has a better overall understanding of a project if he tries to "pull [him]self back out" and gain a broader viewpoint while writing. As an example, he discussed the writing of an expenditure authorization for highway tractors that required him to examine historic data, and researching and writing that document helped him better understand past patterns as well as the business as a whole. Writing "helps you better understand where you are going, understanding the data that you are presenting," he said. Overall, Ed said the act of writing can help one see "the big picture" and facilitate the learning of technical content.

Byron's comments help to account for why writing often fosters a broader or more holistic perspective of a problem or project. Like some other participants, he indicated that the exchange in sharing and debating ideas both orally and in writing facilitates learning. He also noted that the act of writing words on paper has helped him better understand technical and non-technical ideas, and sometimes the act of writing out the problem crystallizes a solution and/or helps him organize the thoughts, including visual ones. Byron pinpointed another benefit of writing in saying that "when you start looking at that [logical written flow of ideas], you not only see perhaps the problem laid out better, but you see the holes in it."

Thomas also commented extensively on the cognitive benefits of writing. Overall, he indicated that he sees writing as a thinking and learning challenge. Referring to his workplace, he said that writing is not

> [...] something [that] on a regular basis a lot people spend a lot of time doing. I do because it's important to me, and I actually look for areas to write. And I mean I write memos to files in part to organize my thoughts but also I know it's a good exercise in writing; [...] at some level there's this part of me that's saying, 'that would really be a challenge to write; let's see how well we can do this.'

He also provided an example in which his work group used writing to try to solve mine-wide efficiency issues:

> We started off by identifying problems. We called them barriers [...]. We came up with 130 of them across the mine site. And we were forced to write them out in verbiage that made sense and in short phrases—'lost production due to too many cable reroutes or frequent cable reroutes,' or whatever [...]. Once we started working on a barrier, the first thing that we do [...] is we set out a goal statement [...]. 'We want to improve the cost per unit and loads per shift in coal productivity [...] by reducing delays and improving cycle times and improving load factors.' Our problem is half solved. We have identified what the problem is, and we have identified where we could make improvement.

Respondent One: "[...] Of course writing helps formulate thought. In the first place every item in the design probably has more than one way it can be done. I encourage my students to write these down and start writing down pros and cons, advantages and disadvantages of each method or system. The simple act of having to list them stimulates thought. Some of this is reiterated in the SD report if it is significant enough that the reader needs to understand the optimization process that has taken place. A SD report can not be done without hundreds of ideas being thought out and either accepted or rejected and measure the affect on other parts of the mine/plant system."

Visual and Textual Thinking

Beyond their comments on the cognitive benefits of writing, and sometimes embedded within them, were participant comments on the way in which many engineers think—namely, in visual form. This section briefly discusses how the manner in which many participants mentally organize information influences the act of writing.

Nathaniel was the only participant who indicated that he generally thinks in words and not in pictures. The other participants who addressed this issue indicated that they often think in visual forms.

Like many participants, Hugh recognized the cognitive benefits that can come from writing, and also like others, he qualified his comments by noting a strong preference among many engineers for visual rather than written forms of communication. "I think if you can use a few charts and graphs, it helps [engineers] understand quite a bit more and goes a long way," he said. He thought that visually representing technical data is a better way in many cases of communicating than putting those ideas into words. Michael agreed, noting that he thinks and learns visually and that "[engineers would] rather cut right to the point of the graph which they really understand than write a whole page that someone has to read through. I think a stereotypical engineer kind of thinks without writing."

Concurring with both students, Ed also said that even though writing yields cognitive benefits, engineers have a preference for visual thinking and communicating. He said that writing to certain (especially non-engineering) audiences can be difficult for various reasons. One is because visual data often tell the story more efficiently and effectively than verbal descriptions, and also because an engineer's eye is trained at "seeing trends in the data" which are generally conveyed most clearly in visual form. Byron agreed with Ed and the students about the visual preferences of engineers, yet he added a qualification. He stressed that engineers do have visual learning preferences and aptitudes, and he provided an example from his own experience. One of his former bosses would ask him for reports that did not incorporate visual information. "When the information that is contained in charts and graphs [is] relationship oriented, to write that out is so inefficient [...]. When you are talking about engineering disciplines and not using graphs and charts, that's completely foreign to an engineer." While a few engineers in his current workplace like to write, in general they "would like to avoid as much writing as possible," he said. However, he qualified these remarks. That engineers generally think visually should not be an excuse for not improving their writing abilities, he said, noting both the cognitive and career benefits for engineers who can write effectively.

Of all the participants, Thomas elaborated most on the visual thinking and learning preferences of engineers. He indicated that part of the challenge in writing is translating visual and numerical data into the appropriate media for communication. "Any engineer is going to prefer a chart, graph, map or table as opposed to a written document [...]. I can say in a table or chart what would take me a page to say in a memo," he said. More specifically, writing is challenging because different thinking processes are involved in thinking about and conveying visual and/or numerical data and verbal information. He gave the example of an intern who recently generated a chart that did not effectively communicate its technical content. Although the intern was thinking visually, he was not thinking about how to communicate his visual thoughts. "Using the right chart [...] to illustrate what you want to communicate is different than thinking in a visual format." And he empathized with that struggle. "We think about it in 3-D, and then we sit there and beat our head up against a wall when we can't explain it in words." Regarding visual and/or numerical information, he underscored the importance of a good narrator or spokesperson. When he responded to the intern who had produced the confusing graph, he said, "'How am I going to explain this to an operator? He's not going to understand this graph; there is too much on it. How can we divide this up and get it so [an operator can understand it]?'"

Thomas also indicated that different tools are best suited to different problem-solving tasks. Sometimes, constructing a visual is the best problem-solving tool. For example, when he recently wrote an options analysis flow chart, he could not write the document until the logic undergirding that visual image was clear in his mind. Although he had originally considered using a matrix, he had to re-conceptualize the problem before comprehending which visual image best conveyed the interrelationships among customer, competitor, and company options. Speaking of a technical problem, he said, "The problem is that kind of 'writing' is actually done in a spreadsheet. You are thinking through a technical problem and if you are going to figure it out, a lot of times, I use a spreadsheet [...]." He said this approach is favorable because the answer to the problem is in a visual or numerical and not a verbal form. "Because things are so visual I can't think of any occasion—in most places, you are trying to solve a technical problem out in the pit. I can think of very few situations where anyone would use writing to solve the [visual and/or numerical] problem." He also noted that engineers' predilections for non-verbal communication are bolstered by that fact that they tend to think visually and that their ability to convey visual information improves with experience. Reflecting on a less experienced co-worker who compiled a chart that would only confuse a non-engineer, he said, "I think where we screw up as engineers is a lot of times we try to put way too much in charts and tables [...]. It makes sense to us because we think visually, but when we try to serve that to someone else and say, 'Now you understand what I am saying?' [The response is] 'No, I don't.'"

For other situations, however, Thomas said that writing can be the best problem-solving tool. For example, he noted that writing meeting minutes not only helps him organize his thoughts but rereading them later helps him in many cases "to sit there and figure out what the logic is behind what we are trying to do. There have been many times that we are working through an improvement initiative that we really don't understand [...] until after I have done the meeting minutes." He said that while numerical and visual tools are used for technical issues, verbal tools are also commonly used to better understand human and non-technical conceptual relationships:

> If a guy is figuring out, 'Okay, what is the sequencing on [the] 103 [drag line] going to be [...] as we go through the next two months to uncover enough coal.' No, there is going to be no writing associated with that. But I think when you start dealing with issues and other people [...], writing can be a powerful tool to figure how everything [works...]. It's all about relationships. To me writing defines [interpersonal and conceptual] relationships.

However, Thomas added, writing can serve as a tool for technical issues that do not involve complex numerical calculations or visuals. "For example, I have a meeting tomorrow [...] and when I wrote the last meeting minutes, I put in bold in a note [...that] we are going to improve our truck cycle time by 0.5 minutes. We never really talked about how we are going to do that [...]. That allowed me to organize my thoughts again, and now we are going to have to go back and attack that issue." He concluded that the nature of the problem influences what problem-solving tools are used and that generally writing is a learning tool for non-technical problem solving while visual/numerical tools facilitate technical problem solving; this is because writing brings clarity to verbal problems but not necessarily to visual and numerical ones.

Although interviews provide the bulk of data for this study, documents and observations substantiate participants' comments on visual thinking. Illan provided several sample SD final reports, each of which fits into a large three-ring binder and contains only brief passages of text interspersed by maps, drawings, other graphics, and numerous references to appendices, which themselves often represent a thicker proportion of the total report than the textual descriptions. That visual images are frequently marshaled as evidence in support of brief textual claims was also apparent in the May 1, 2003 SD oral presentations. Using

PowerPoint slides, SD students discussed their project objectives, methods, results, and implications with remarkably little text. Even more than in the written final reports, visual images dominated the oral presentations, especially maps, aerial photographs, and diverse graphs. Post-presentation questions often centered on visual images as well, suggesting that visual images, as the participants indicated, generally convey technical content more effectively and efficiently.

While most of the participants recognized the cognitive value that can be gleaned from writing, their overall notions of the value of writing, as will be described in the next chapter, are far more complicated.

Respondent One: "I encouraged my students in SD to use visual aids at every opportunity; in their report as well as in their presentations. Some things, ore body shape and mine plans almost have to be visual 3-D pictures to really be understood. Equipment and drill/blast pattern layouts are other examples of what really needs to be shown as a picture or drawing. However, they must also back up the drawing with calculations from which drill/blast patterns were designed; i.e., they are not just pictures; they are the graphic results of a design. Graphs and tables are also needed to simplify the presentation to the reader or listener. All of these should be used as much as possible in the SD report and presentation."

Researcher Commentary: Writing and Thinking

Since the way in which we write is tied to, among other complex factors, the way we think, and since thinking and learning styles vary widely, it should be no surprise that participant views on how writing and thinking interrelate differ. Yet several overlaps also occur among participants.

Collectively, participants' thoughts regarding writing and thinking provide significant support for writing-to-learn and writing-in-the-disciplines theories that describe writing as a complex activity which facilitates the learning of content and of disciplinary discourse patterns (e.g., see Berkenkotter, Huckin, & Ackerman, 1988; Young, 1999). In fact, many participant comments read as though they were lifted from the pages of texts championing writing as an effective learning tool. Almost all participants stated that writing in some way facilitates comprehension and retention of information. For example, Michael, Ed, and Byron noted that the act of writing brings a "big picture" or holistic perspective on the myriad details of a project. Intriguingly, although the act of writing is often described as a recursive, chaotic process, some participants in this study said the act of writing brings greater clarity and focus to relatively chaotic *technical* processes. For example, Michael commented that he sometimes simultaneously devotes his attention to multiple technical tasks, jumping from one to another, and writing brings order and coherence to this disjointed process.

However, participant comments reveal that individual thinking and learning styles complicate the process of making generalizations across *all* participants' views on writing and thinking, even among a group of people with similar disciplinary backgrounds. For example, while other participants commented on engineers' predilection for visual thinking, Nathaniel said he thinks in words and not in pictures. Furthermore, Nathaniel, while he recognizes other cognitive benefits for writing, was also somewhat anomalous among participants in indicating that writing is not relevant to technical problem-solving processes. By contrast, Byron indicated that the act of writing on technical topics not only helps one organize one's thoughts and better understand the problem, but it also ferrets out logical gaps or specious assumptions. These findings suggest that all participants see writing as a tool for learning, and the majority use writing as a tool in technical problem-solving situations.

Thomas's comments on this matter help pinpoint the situations in which he uses different types of problem-solving tools. According to Thomas, a problem represented in the mind in one way tends to be solved in the same way. So a problem primarily represented visually tends to be solved with visual tools while a problem primarily represented verbally tends to be solved verbally. That also means that numerical and visual tools are generally used for technical issues, and verbal tools are commonly used to better understand human and non-technical conceptual relationships. However, he did add that writing is at times a heuristic for technical issues that do not involve complex numerical calculations or visuals.

Collectively, Thomas's comments provide support for the dual-coding theory, which holds that we mentally represent information in two distinct coding systems—verbal and imaginal (Paivio, Clark, & Lambert, 1988). Although an oversimplification, coding information refers to the process of putting information into a form we can understand and remember. According to dual-coding theory, we use verbal representation when thinking about words, sentences, and other experiences stored in our verbal coding system, and we use our imaginal coding system to store nonverbal information such as pictures. This would help explain why a problem represented in one system would tend to be solved using tools in the same system.

At the same time, re-representing information in another system could have other cognitive benefits, which will be explored in the next chapter. Many participant responses regarding writing and thinking also suggest ways in which participants value writing, and thus these will be addressed in more detail in the next chapter.

Implications for Practice

Participant comments on writing and thinking suggest that even among a small group of individuals within the same discipline, thinking and learning styles vary. This should encourage engineering educators to continue considering the vast array of ways in which engineering students learn diverse types of material given their multiple intelligences (see Gardner, 1999). Often, learning to write involves unlearning bad habits and learning reasons for new, more effective strategies. This generally occurs as one discovers how one best learns complex new concepts or tasks. The ways in which any individual best learns is as unique as his or her fingerprint, and over time, we gain greater insights into the nuances of our own learning styles and multiple intelligences. This self-knowledge facilitates learning of strategies that are vital to learning how to learn new material.

Engineering educators have long focused on how design processes and design products are interrelated, and we could make similar extensions to writing processes and products within and beyond discussions of design processes. Actively fostering such reflection on writing and thinking approaches as components of problem-solving processes would probably appeal to engineers as they develop broader, interdisciplinary problem-solving strategies and as they see writing as a component in engineering problem solving.

References

Berkenkotter, C., Huckin, T. N., & Ackerman, J. (1988). Conventions, conversations, and the writer: Case study of a student in a rhetoric Ph.D. program. *Research in the Teaching of English, 22*(1), 9-41.

Gardner, H. (1999). *Intelligence Reframed: Multiple Intelligences for the 21st Century.* New York, NY: Basic Books.

Paivio, A., Clark, J. M., & Lambert, W. E. (1988). Bilingual dual-coding theory and semantic repetition effect on recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 163-172.

Young, A. (1999). *Teaching Writing Across the Curriculum* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

CHAPTER 10: THE VALUE OF WRITING

"Engineers [who] fail to communicate will not advance beyond a level where somebody else will do that communicating for them. If they are happy sitting in a cubicle using AutoCAD and having someone do the writing for them, they are going to fix themselves at a particular salary level, at a particular job within in organization, and ultimately will become unhappy in that job because we all like diversity."

--Byron

"It doesn't matter how good my ideas are. If I can't communicate them, I am going nowhere."

--Thomas

"I think we [...]do the technical work and have all these pretty charts and graphics; from the technical point of view, we think you can look at that and figure out what went on and what the conclusion would be. So we don't want to do the writing part because we already did all this technical stuff and there it is in graphical and tabular form; why do I have to explain it?"

--Michael

"[...] in general engineers would like to avoid as much writing as possible because that's the way they are wired. They are wired with diagrams and pictures and the like and they think that way and don't see the need to write it down."

--Byron

"We think about it in 3-D, and then we sit there and beat our head up against a wall when we can't explain it in words."

-Thomas

Indirectly or directly, participant comments in the five preceding chapters speak to the ways in which these engineers value writing. Chapters 7-9 most explicitly address the value of writing, and participant comments in these chapters might lead one to believe that participants recognize the importance of, value, and perhaps even enjoy writing. However, those who have worked with engineers in academic and/or corporate settings know that engineers' common attitudes about the act of writing are generally not so positive, and findings described below confirm these attitudes. What could account for this disconnect between the results of this study, which indicate on the one hand a strong recognition of the importance of writing and on the other a negative attitude toward the act of writing? One may hypothesize that while engineers might recognize the importance of writing in the abstract, they may not necessarily value it highly in everyday practice. And it would follow that if they don't value writing in engineering practice, they may be unlikely to enjoy it. But the findings from this study do not fully support such a conclusion. Rather, participants' comments about the value of writing, as described in Chapter 9 and below, often sound as though they were lifted from the pages of a text championing a writing-to-learn or writing-across-the-curriculum initiative. Yet despite this strong valuation of writing, the study participants unequivocally acknowledged that they do not enjoy the act of writing. The complex and interrelated reasons for this affective view are also detailed below.

How Writing is Valued: Knowledge and Career Advancement

Participant comments regarding the value of writing centered on issues of knowledge and career advancement. As will become clear, these two valuations are interrelated.

Knowledge Advancement

Some participants indicated that writing facilitates an understanding of new technological developments that can have industry-wide implications. Both Michael and Hugh, for example, indicated that new knowledge often must be written for it to be disseminated and used. Michael noted that professional journals play a significant role in circulating new ideas, and Hugh added that mining engineers often are moved from mine to mine and maintain contact with former colleagues via email. As new products come on the market, Hugh indicated that this network of colleagues shares information on product effectiveness.

The other aspect of knowledge advancement involved documenting work for historical reasons, so engineers in the future have a written account of technical evidence, actions, and the rationale for decisions. Ed, Byron, Thomas, and Nathaniel all underscored the importance of documentation, especially for safety and legal reasons. Some participants mentioned that such documentation also guides innovation and serves as the baseline for future improvements.

Respondent One: "One comment on technical writing for professional development; in spite of our best effort to get young professionals to write and submit papers to their professional societies, few do so. In the national competition that SME holds every year for various categories of students and young professionals and award the winners $500 and a free trip to the annual convention, they never get more than 4 or 5 papers from the entire country in each category. Young professionals today are just interested in other things. In contrast, by the time that I had worked in industry for the first ten years, I had published at least a half of dozen papers. In fact some entire portions of our industry almost refuse to write technical articles about what they are doing. The crushed stone/quarrying industry falls into this category. This leads into the next subject; those who write and publish, even if you are not in academia, will certainly open new job opportunities. It worked for me."

Career Advancement

Certainly, knowledge advancement is tied to career advancement; if mining engineers successfully add to their field by developing innovative and effective technologies, they will receive greater recognition among peers in the field and within their organizations, whether those are in industry or academia.

When discussing the role writing plays in advancing one's career, participants addressed the two intertwined issues of recognition and promotion. To be promoted, one must gain recognition, and writing plays a vital role in this process. Participant comments on gaining recognition for their work included the themes of saving time, providing project updates, securing readers' understanding of technical ideas and increasing the usefulness of those ideas.

Saving Time

As noted in Chapter 8, Hugh realized that truly effective writing saves time for one's peers and/or superiors. During his internship, Hugh analyzed an alternative haul route and wrote a summary of the advantages and disadvantages of various routes, but he indicated that he was somewhat taken aback when his supervisor then asked for a definitive and persuasive route recommendation from him. In retrospect, however, he realized that an account of the pros and cons of various methods "just gives [the supervisor] more work to do."

Respondent One: "I'm shocked that Hugh did not expect the boss to want a recommendation. After, all he was the one that at that point in time knew the most about the subject and therefore he was being paid to also produce a recommendation!"

Byron, from his perspective as division president of a large company, had much to say about the value of writing that saves time. He emphasized the intense time-pressures, and indicated that concise, precise writing that has some minor grammatical or surface errors is preferable to writing that may be correct, eloquent, but wordy and inefficient:

> I have four general managers, three of the general managers are college degreed and two [...] have MBAs; one of them has a high school education. [...] the fellow that just has the high school education [...] doesn't write well at all [in terms of] grammar usage [...] spelling and punctuation. But the ideas that he conveys are conveyed very concisely, and I appreciate what he gives me more so than the MBA write ups, which contain a lot more proper flow of the document.

Byron also underscored how effective workplace writers save their coworkers' time through appropriate distribution and summarization. Engineers need, he said,

> an understanding of the proper distribution; when you get a memo, and it's been copied to everybody and their brother, that's not appropriate. Everybody and their brother does not need that information. The other thing too is summarizing appropriately, and that may be as much art as it is science. I don't need to know every meet and bound of a survey when I am looking at a property purchase. I don't need a description of every property corner. I just need to know why we want it, what it's for, what it's going to cost, and why we think it is a right thing to do.

Thomas's comments confirmed those of Hugh and Byron. He said that someone in a management position will value having "people underneath you [whom] you can count on to write well-written documents and to organize their thoughts clearly [...] because it saves you time, and saves you energy." On this point, Nathaniel agreed with Thomas, but Nathaniel also noted generational differences in this valuation, saying that people 50 and older in positions of power tend to value writing more than younger professionals.

Respondent One: "We all talked about it above: the best way to save time for the reader is to present the information graphically/pictorially."

Providing Project Updates

Others commented on the value of writing that provides project updates. For example, Michael noted that during his internship, he wrote to and received from co-workers daily email memos that described progress to date on the various ongoing projects. Also, Thomas explained that keeping coworkers up to date is crucial for success in his leadership position:

> In the job that I am doing now with these improvement initiatives, the ability to communicate those initiatives mine-wide—40, 50 people at a whack—is

> absolutely critical. I have got to keep everybody updated because change is simply the hardest thing that you do in mining. To change people is just incredibly difficult, and the number one reason is because of the lack of communication.

Securing Audience Understanding

Beyond saving time and providing project updates, many participants also emphasized the value of writing in securing readers' understanding of ideas, especially technical ones. This is particularly understandable in the mining industry due to the breadth of inherent, potential safety risks as well as to the need for increased efficiency to remain competitive. For example, Michael noted that his professors often reference books and hand out journal articles. One professor hands out articles almost every class because "he sees that there's a lot of value in these papers and that by reading it, you'll learn a lot. He's a professor now but he was a practicing mining engineer, so I think he really sees the value of reading what's been done before," he said. Hugh added that the ability to "express [...] new knowledge is important to being able to sell it. If people can't understand what you're saying, then they won't get the gist of how important this new knowledge is," he noted. As mentioned in Chapter 8, Byron voiced the same idea when he noted, "The only way to communicate your ideas and get from line drawings to actual build is to be able to justify what you are doing with the written word. The drawings alone are not understood by senior managers," who may have degrees in anything from marketing or finance to accounting or law—which underscores the value of being able to convey technical ideas to non-technical people, he noted.

Respondent One: "It isn't just in academia that we need to convey new ideas to others. Any time that you are trying to introduce a new way of doing anything, you must be able to convey the benefits of this new system to others (both up and down)."

Increasing the Usefulness of Technical Ideas

Once people have clearly understood a technical idea and its implications, they are much more likely to put it to use, participants noted, and the application of one's ideas augments one's recognition and reputation. Hugh said that one's reputation as a writer and as a professional are particularly important in the close-knit mining engineering "community," in which it is crucial to "build good relationships when you have the chance and don't burn bridges because you're going to be dealing with the same people probably your whole career." Rikard also explained that effective technical ideas may neither be used nor receive merited recognition if the ideas are confusing. "If something is not clear, then it means that it takes a long time to understand, or it may have even been misinterpreted," which could waste valuable time and resources, he noted. Ideas "of great technical value" might not be incorporated into a project because the ideas are not readily understood, which could lower the value of the project, underscoring the importance of having a "clear, intelligent [...] supporting document," he said. Similarly, Hugh indicated that one of his criteria for effective writing in mining engineering is based on whether he can understand what is being portrayed on a careful first reading.

Thomas indicated that he is motivated to write if the problem he has solved is "information to someone. Nobody knows that you have solved the problem, so you have to communicate it to get [...] recognition for what you have done." However, many participants noted that just as effective writing can gain one recognition, poor writing can as well—but clearly less desirable recognition. For example, Hugh indicated that if a consultant produces unprofessional writing, that consultant can be stigmatized for the rest of his or her career. He added that unprofessional writing in any workplace context "reflects poorly on you as an employee." Two participants even described the inability to write effectively as a disability. Illan said that discomfort with writing is a "handicap," and, also unprompted, Byron used the same analogy: "the inability to communicate in the written word would be the same limitation that society would place on a blind person, a deaf person or a mute person. You can still get along but accommodation has to be made for that person in some other way."

Thomas also commented on the negative professional impression poor writing can create. Describing an audit conducted by a consultant with 40 years of mining experience, Thomas said, "He came out and did an audit of our site and was able to pick out some really key things and really quickly. And when he wrote it, it was all crap. I am reading this thing and thinking, 'God, as a freshman in high school I could have written this better than you.'" Thomas emphasized that even though co-workers have the opportunity to change these impressions of their professionalism, writing provides a first impression of how co-workers' regard the quality of their own work. For example, he said that "people make judgments about what kind of person you are based on how you write your email—who you send it to, how you word it, whether or not you are trying stir the pot or just trying to provide information." In describing a colleague adept at provoking and sometimes alienating co-workers, Thomas noted that this colleague, "[…] is just trying to get people upset, and it really irritates people [...]. He could say the exact same thing in a different way, and be a lot more effective at what he is trying to get across."

The ability to gain recognition through writing is part of building ones' professional reputation, but only part. Thomas and others indicated that multiple skills must be present for success and promotion. Both Thomas and Byron thought that oral communications skills are more crucial than writing skills in gaining recognition and building a reputation. Additionally, strong problem-solving skills are crucial; Thomas said, "[...] you can be a great writer, and if you are not a good technical engineer you are not going anywhere." This multiplicity of skill sets is particularly pronounced in a field like mining engineering, where success depends on multidisciplinary knowledge. As Nathaniel noted, "to practice mining engineering, you have to be a little of a civil engineer, electrical engineer, mechanical engineer, a little bit of a geologist, some part economist." Compared to other engineers, Byron noted, mining engineers are "jacks of all trade" and tend to be able to problem solve in any situation that involves hard rock mining, coal mining, coring, geo-construction or movement. "You can put them into any situation and they have a set of tools that they can find you an answer and get something done. They generally think pretty well on their feet." Byron added that other engineers generally have less diversity; he described a friend who works in the tractor division at International Harvester and does nothing but write hand controls. Because mining engineers are immersed in such a wide range of problem-solving situations, he thinks they are often strong candidates for senior positions within an organization.

These remarks were issued with caveats, however. Some promotions would be impossible without the ability to write effectively, Byron said. That is, not only do weak written communication skills lower one's value to the organization, but also they render one ineligible for certain promotions. "So it's harder to be considered for promotion if you don't write well at the lower levels; [effective writing skills are] mandatory at the upper levels to be considered for promotion." Byron added,

> Engineers [who] fail to communicate will not advance beyond a level where somebody else will do that communicating for them. If they are happy sitting in a cubicle using AutoCAD and having someone do the writing for them, they are going to fix themselves at a particular salary level, at a particular job within in organization, and ultimately will become unhappy in that job because we all like diversity.

In that sense, he said, "[…] being unable to communicate in the written word will cap your career at a certain point because it's required at that point."

Illan agreed with the idea that effective writing skills facilitate promotion, noting his own transformation from a teenager afraid to write even a postcard to a highly confident technical writer who was recognized and promoted because of his writing. He acknowledged that even while working in industry, writing was still a struggle for him, and "[...] just to write a two-page memo, I would take a couple of days." He did so partially because he wanted to make sure each statement he made was justified with sufficient technical support, and that careful approach earned him special notice. As noted in an earlier chapter, members of the upper management in his company, although they were in California and he was in Colorado, made a point to meet—and later, promote—him, and their only way of knowing him initially was through his writing. For Illan, persuasive writing plays a more significant role in industrial engineering than in academic contexts because upper management and others frequently make financial and other decisions based on the quality of logic and evidence in written documents. Illan added that although he struggled with writing through much of his career, he does not struggle now. "After writing close to 50 technical articles, reviews, papers, over 10 research reports, it's not difficult for me; I feel very comfortable." When asked about that transformation, he noted that "the only way that I think you gain that is through experience. And keep writing, keep writing. The more instruction we give to our students here on writing, the better they will get at it." When asked to elaborate on how he had transformed from a struggling writer to a fluent, efficient one, he said that most pivotal were his "years of experience and practice [and] forcing [him]self and doing it."

Ed also saw a direct connection between effective writing and promotion. Workplace writing, he said, reveals much about one's ability and problem-solving approach, which informs managerial decisions about individuals' work quality. Overall, he indicated that writing is "very important" because effective writers "do better in their career than people who don't write as well, just because they can convey their thoughts and ideas, and it shows that they have done the work to back up the document." Even though only 3-5 percent of his average workday is spent writing, including email, on a scale of 1-10, where 10 is of utmost importance, he indicated writing is a nine or 10 in terms of its role in promotion. He said that writing has become "more important now rather than when I started 15-16 years ago." Ed also emphasized that many engineers are "bogged down" by safety, contract, and other administrative tasks, leaving little time for reading and writing. This workplace reality makes the ability to write quickly yet effectively all the more valuable, he said.

Although writing occupies less than 10 percent of Byron's average workday, he also believes engineers have augmented their recognition for the importance of workplace writing, especially in the last ten years because of several factors. These factors include changes in academic curricula, increases in record-keeping requirements in industry, and wider social changes, including technologies such as personal computers, email, the Internet, palm pilots, and others that are largely oriented towards words. When asked to rank the role of writing on a 1-10 scale, Byron said that "it would depend upon the level of the individual as far as the promotion goes. The number goes up as the level of the job goes up."

Thomas also emphasized his writing as one of the vehicles for career advancement. He said that writing occupies 15-20 percent of his typical workday. When asked to rank writing's role in promotion, he said that writing would be between a four and a five, while communication in general would be a nine. That his superiors perceive him as an effective thinker and communicator has landed him on projects that he would otherwise not have been involved with, and the documents that he has written for those projects have earned him recognition from superiors. He noted that, "[...] the majority of the impressions that exist outside of this mine site on my abilities as an engineer either come from a presentation that I have done [...] or something formal that I have written." Thomas added that his general manager (GM) recently focused his determination to continue improving his writing; the GM said that although he did not know exactly how one goes about learning to write well, "'The best thing that you can do for your career is to learn how to write well.'" Thomas said, "It doesn't matter how good my ideas are. If I can't communicate them, I am going nowhere."

Reasons for Attitudes toward Writing

The above comments indicate that participants generally value writing, and in some cases value it highly. However, most participants qualified these comments by acknowledging that they and their engineering colleagues do not value writing as much as they should. For example, Ed said, "I think [writing is] very valuable, but [...] I just don't think we put enough effort into it." It is noteworthy that when asked, both students indicated that their fellow SD students may have been reluctant to participate in this study because of, as Michael put it, "that stigma towards writing. They hear writing, and go, 'oh, if I have to write a paper, I don't want to have anything to do with that.'" Although participants were explicitly informed that the study did not require them to do any extra writing, the topic of writing was apparently enough to keep some would-be participants from becoming involved. This tension between their valuation and attitudes about writing can be partially accounted for by examining the complex reasons for participants' attitudes toward the act of writing. These reasons are not completely discrete units. Rather, most are mutually shaping influences that in highly complex ways affect each other, an issue explored more below.

1. Writing Takes Time

Many participants emphasized the intense time pressures in their workplaces. Writing takes time to do well, and time is a precious commodity in short supply, Thomas noted. Ed said he thinks that most engineers probably regard writing as a "nuisance" because it takes more time to do well than is generally available. To illustrate, he recounted details of his current project in which his timeline from six months ago included time set aside specifically for writing.

But inevitably, he said, that time was consumed with more pressing tasks. He recognized that "it would have been more helpful to me if I would have finished a certain part of the project and sat down and spent a couple of days writing on it, or maybe even half a day to a day" but that proved to be unrealistic. Now he will have to write from more distant memory. Part of these time pressures, Ed added, emanate from an industry-wide focus on efficiency in which operations are run "lean and mean [...] so you tend to do things that you normally wouldn't do or are not used to doing."

Respondent One: "I have two comments. First, the SD students should be writing all through the feasibility and evaluation process as they complete each portion. Second, most of my technical articles that were written and published throughout my career were written at home on my own time. This elevates some of the pressure of trying to do it at work. I'm not sure that most engineers today would want to do this."

Engineering workplaces are no doubt permeated by the tension between time pressures and the need to take time for writing. Yet because this description fits the vast majority of workplaces, what Byron called engineers' "affinity [...] to avoid writing" must be shaped by other influences as well.

2. Academic Training is Not Focused on Writing

Some participants noted that writing is not the focus of engineers' academic training. For example, Hugh said that engineers' writing attitudes may stem from the fact that their academic training primarily focuses on math, science, and problem solving, and not writing.

He added, "I've noticed that a lot of engineers do have trouble writing, expressing themselves, and so I think they realize that they probably have those deficiencies."

3. The Technical Comes First, All Else After

Other participants noted engineers' interest in technical problem solving, to which all other issues tend to be secondary. For example, Michael described the way he thinks many engineers regard writing by saying that, "[...] I think sometimes you write a little too complex, too confusing, too many big words, too many long sentences [...] because we don't think about the writing part of it as that big a deal. We think about the technical part of it as being the big deal." Byron said that while he may not agree with this attitude, he certainly understands it; since many engineers went to school to solve technical problems and design technical things, he noted, they often view writing as tangential. Thomas also confirmed that among engineers writing is generally marginalized

> [...] because [engineers] are technical people. They are trained be technical; they're trained to be analytical and critical in their thinking, and [...] the belief is that, where the value is, what's going to promote your career is finding that problem or being able to solve that problem, or being able to create these big spreadsheets and analyze things. But in truth, that's all great, but if you can't communicate it, [...] what good has it done you?

Respondent One: "I think that for the above two subjects (2 & 3) these engineers are selling us short. I found that most graduating mining engineers wrote pretty well."

Since time pressures, academic foci other than writing, and technical interests exist within many other professions that also require writing as a professional competency, other factors must also influence the writing attitudes commonplace among most engineers.

4. Mentors Play a Role

Some participants indicated that oral communication skills are more valuable than written ones. For example, Rikard indicated that one of his early and influential career mentors did not value writing. And that mentor had told him, "'Why should you write about something? If [colleagues] need something, they should come and ask.'" A student in Rikard's SD course, Hugh also noted the influence of mentors and added an important demographic detail. Many mining engineers are non-native speakers of English, and "when that's the case I think writing becomes even less important because their grasp of English isn't as great," especially when they are your professors or supervisors, he said.

It is noteworthy that a majority of the faculty and a significant percentage of the graduate student body in Hugh's mining engineering department are non-native speakers of English, including Rikard and Illan. However, mentors could have other influences, as they did in Thomas' case. Thomas' generally positive attitude toward writing was bolstered by a company mentor, who recently told Thomas that the best Thomas could do for his career is to learn how to write well.

Respondent One: "Again, I agree that it is very important for engineers to write. His writing will improve the more that he does it and the more peers review his writing."

5. Oral Communication Ranks Higher

Commenting specifically on the process of establishing and maintaining good business relationships, Byron noted that oral is more important than written communication.

However, he qualified this by noting that writing plays a role since poorly written documents can damage or destroy interpersonal relationships and appropriate written compliments can strengthen them. Byron also highlighted the role of oral communication in workplace socialization. As in most workplaces, effective colleagues develop rapport by being neither too standoffish nor excessively social, he said. They can put people at ease, treat others as human beings, and express and support opinions, and he added that oral abilities play a more significant role than written ones in such interactions. Thomas concurred that while writing plays a role in conveying your competence, oral communications, both informal and formal, play a more significant role. He added that this is true in part because so much of his workplace communication happens orally.

Respondent One: "It is nonsense to argue which is the most important. Both are very important and the most successful mining engineers will be those who can do both well, as well as have a good technical and financial background."

6. Writing Improves with Practice—And Atrophies without

Thomas acknowledged that the act of writing becomes less difficult with practice but more difficult when it is not practiced. He noted that, because of the nature of many projects, engineers' writing skills sometimes atrophy through lack of consistent use.

7. Writing Induces Fear

Illan listed fear of writing as one of the reasons for writing avoidance tendencies among engineers. He indicated that as a student, he sometimes studied for exams by writing.

However, he said that students with a strong fear of writing would be less likely to use writing as a tool for learning, thus limiting the development of their thinking skills.

Of course, a fear of writing itself stems from other causes, and the reasons listed below may help explain the origins of this fear.

*Respondent One: "I think that **laziness and lack of priorities** is a more important factor than fear!"*

8. Writing is Difficult

Many participants' comments implied that they recognized that writing is a cognitively complex task. Nathaniel more explicitly noted that "engineering writing [...] is for a specific purpose; it's factual, and it's technical, and there is no opportunity to express how you feel about it. It's [...] not something you do for pleasure." Writing, he added, is also a complex activity that people generally do not understand.

Respondent One: "What is so difficult to putting down on paper words that report your experience or findings about some subject?"

9. Writing is Non-Linear and Tedious

One of the reasons some participants perceive writing to be difficult may rest in its non-linear nature. Thomas commented specifically on writing as a non-orderly process.

> When you actually have to start putting numbers and figures and values and you have to be very precise in what you are writing, that is tedious. And it's

> time consuming because chances are you're having to go to different sources, different documents, looking up numbers; you don't have them all in your head, and you don't have them summarized anywhere. So you are flipping through binders or maybe through spreadsheets or different files [...]. It's tedious [...] and it's very disjointed.

Respondent One: "This statement validates my 'laziness' theory."

10. Writing is *Post-Facto*

Adding to the above reasons, some participants noted that the challenge of workplace writing is exacerbated by its timing within any given project. During Michael's internship, he worked on a medium-sized report involving a truck weight/truck payload study, in which the writing occurred after the data had been gathered and the problem solved. Thomas reiterated that engineers enjoy technical challenges, and writing frequently occurs after the technical problem has been solved. Thus, writing is perceived as a tedious post-project chore. "When it's just pretty much run of the mill, and I already know what the conclusions are [...] I really don't want to do it. A lot of times I make the operators do it [...], just farm it out."

Ed agreed that when the engineer's goal is to solve a particular engineering problem, and the visual and/or numeric data have helped solve that problem, the project is essentially finished. Therefore, the act of writing up project results is outside the problem-solving process and is viewed as particularly onerous. Nathaniel also concurred that writing generally occurs after the problem has been solved or the issue has been resolved. He said that less commonly, writing can occur at the outset when the parameters of the problem are being defined to help "quantify it, get a handle on it" and decide pertinent materials, quantities, issues, constraints, objectives, and methods. While writing is used at the end and possibly at the beginning of a project, it is not useful in the middle, Nathaniel said.

Respondent One: "Pardon me for being crude, but a technical project is not done until the paper work is done. Again it sounds like the 'laziness' factor is a part of the problem."

11. Writing is Not a Technical Problem-Solving Tool

After Nathaniel noted that writing is generally not useful in the middle of a project, he added that most technical engineering problems do not lend themselves to using writing as a tool to facilitate problem solving, primarily because the technical data are numerical data, and tests or other measurements frequently facilitate problem solving. In that sense, he indicated that the scientific method contributes to rendering writing less useful during problem solving since engineers are often testing the validity of hypotheses via technical and numerical but not verbal means. Thomas held the same view, noting that writing is generally not an integral tool in the problem-solving process, although writing can serve as a tool for non-technical problem solving; he said this is because writing brings clarity to verbal problems but not necessarily to visual and numerical ones.

Respondent One: "I can't believe these remarks. At the completion of the project, you just might want to sell the results to your supervisors, or document the solution to the problem so that when it occurs again, the solution will be well documented. There are so many reasons why the results of a project or technical study need to be documented."

12. Data Speak for Themselves

Michael indicated that because technical data generally speak for themselves, the act of writing is perceived as superfluous.

> I think we go and do the technical work and have all these pretty charts and graphics; from the technical point of view, we think you can look at that and figure out what went on and what the conclusion would be. So we don't want to do the writing part because we already did all this technical stuff and there it is in graphical and tabular form; why do I have to explain it?

For this and other reasons, he noted, "there's animosity towards writing."

Respondent One: "This does not reflect my experience nor of those [with] whom I have been associated."

13. Thinking without Words: How Engineers Represent Technical Information

Many participants noted that engineers have strong aptitudes and interests in science and math, and often low aptitudes and/or interests in writing. This may be what Thomas was referring to when he called engineers, "technical people" interested in solving technical problems. Correlated with these aptitudes are ways of thinking and knowing. In describing these, Michael noted, "I think a stereotypical engineer kind of thinks without writing." He and other participants described engineering thinking styles as largely non-verbal, numeric and visual. As described above in Chapter 9, Byron indicated that writing avoidance stems in part from "the way [engineers] are wired." Just as lawyers like to read and debate, engineers like to design and solve technical problems, he said. While engineers recognize that they need to communicate with others within an organization, they often consider that others ask for too much written explanation, especially when the same information could be conveyed more efficiently in graphs, charts, and other visual media. Byron added that, notwithstanding a few exceptions, "[…] in general engineers would like to avoid as much writing as possible because that's the way they are wired. They are wired with diagrams and pictures and the like and they think that way and don't see the need to write it down." Ed and Hugh also voiced a similar perspective.

Respondent One: "None of the above says that engineers should not also be prepared to document the results of their work."

14. Writing Entails Translating from Numeric/Visual to Verbal

In the second interview conducted for this study, Illan made the remark that workplace writing often involves writing to non-engineers so, for example, he had to "translate [technical language] into the language that higher management can understand." At the time, the word "translate" did not seem noteworthy. However, when participants interviewed after Illan began commenting on the same phenomenon, the notion of *translating* technical ideas into audience-appropriate language became a recurring theme among other participants; this theme has been examined in Chapter 9 yet merits revisiting here. Michael commented indirectly on the translation theme while explaining why engineers do not value writing as much as they should. One possible reason was due to the way engineers process and think about information, which as noted above focuses on the technical more than the verbal aspects. He said that writing is difficult because even though engineers might thoroughly understand their technical designs, "[…] we kind of get bogged down a lot […] and when it comes time to *put into words* so that other people will understand, it's kind of difficult [emphasis added]".

Ed concurred that one of the difficulties in writing, especially to non-engineers, is the act of translating visual, technical data into words. This is an act of "translation" since the technical visual media such as graphs, maps, charts, and tables, must be converted into non-technical, everyday layperson's language.

Respondent One: "The graphical pictures are just as valuable to the non-technical reader as they are to the technical reader. You can still explain it in words so that the non-technical reader will understand the graphic."

When asked about this translation concept, Byron noted the translation involves shifting from one way of thinking to another. He said, "There is an affinity that engineers have to avoid writing, I think in general because they do think in pictures and diagrams and the like." As an example, he shared an experience involving a previous boss who asked for written documentation without graphs and charts. He said that

> [...] when the information [...] contained in charts and graphs [is] relationship oriented, to write that out is so inefficient that it blew me away that he asked me to do that. And when you are talking about engineering disciplines and not using graphs and charts, that's completely foreign to an engineer [...]. Now I didn't have a problem writing the conclusion from the graph or writing the activities that should take place relative to the conclusions in a graph, but to avoid the graphs and charts completely was very inefficient.

However, Byron qualified his statements by saying, "I think if you ask them to write things down, they are better engineers."

Although Nathaniel said he thinks in words and not in pictures and thus does not have to translate into words, he was the only participant who expressed this viewpoint. By contrast, Thomas agreed that writing can require a complex act of translation. Engineers may need to convey data in verbal form after they have both represented and solved the problem in visual and/or numerical forms, he said. Part of the challenge in writing is translating visual and numerical data into the appropriate media for communication. "Any engineer is going to prefer a chart, graph, map or table as opposed to a written document [...]. I can say in a table or chart what would take me a page to say in a memo." More specifically, writing is challenging because different thinking processes are involved in thinking about and conveying visual/numerical data and verbal information. Thomas gave the example of an intern who recently generated a chart that did not effectively communicate its technical content. Although the intern was thinking visually, he was not thinking about how to effectively communicate his visual thoughts, and Thomas empathizes with that struggle: "We think about it in 3-D, and then we sit there and beat our head up against a wall when we can't explain it in words." Regarding visual/numerical information, he underscored the importance of a good narrator who understands his or her audience. When he responded to the intern who had produced the confusing graph, he encouraged the intern to convey the information in a way that non-engineers would understand it, to try to see as they see.

Researcher Commentary: Value of Writing

The findings of this study do not suggest that participating engineers failed to recognize the value of writing. Indeed, their statements about the value of writing were quite positive overall. Yet their valuation of writing is tempered by negative attitudes toward writing, and many of the reasons for these are clearly interrelated and reinforce one another. Exactly how the reasons might mutually shape each other must vary from individual to individual since writing and thinking styles are inextricably intertwined. Yet some clear mutually formative relations may run across participants, and perhaps other mining engineering writers.

The reasons participants listed for their attitudes toward writing are mutually reinforcing, and one could propose multiple possible configurations of intersecting factors, only a few of which are mentioned here. This first configuration, including reasons 1, 2, 4, 6-8, may not be unique to mining engineering or even to the broader field of engineering. This compilation may also apply to multiple scientific disciplines. Specifically, it may not be profession-specific because in many professions writing is 1) time-consuming and performed under tight deadlines, and because 2) professionals often lack training or instruction with writing, especially writing in their discipline and profession, including writing in profession-specific and organization-specific genres. When we add to this mix the facts that 6) writing skills atrophy through disuse, that 8) writing is an inherently complex cognitive task, and that 4) mentors sometimes discourage the development of writing skills, we can see how each of these elements may not act alone but be mutually reinforcing. Further, each of these elements can cause and/or be caused by 7) a fear of writing.

A second potential configuration involving reasons 3, 5, and 9-14 may apply more specifically to mining engineering and possibly engineering generally. The engineers in this study tended 3) to highly prioritize technical aspects of their work, and in some cases rendered non-technical factors a distant second. Combined with this is a group of professionals who seem 5) to value oral over written communication skills and 9) to describe the writing process as disjointed and non-linear. However, this latter viewpoint is contested, as some participants also described writing as a process that gives structure and order to otherwise disjointed technical processes of investigation. Some engineers in the study noted that 10) writing is also done after the technical problem is solved and thus seen as tedious and irrelevant to problem-solving; in fact, some participants did not 11) perceive writing as a tool for technical problem solving. When we layer on these reasons the idea that 12) the visual and numeric data speak for themselves and that 13) many engineers think visually, this collectively reinforces the marginalization of writing. All this is further complicated by the fact that 14) technical writers must often engage in a two-stage process when communicating to non-technical audiences: translating first from visual and/or numeric to technical words, and then from technical terms to non-technical terms. Again, these two configurations are only two of many possibilities, and are given here to underscore the mutually formative nature of the reasons participants provided for their attitudes toward writing.

Value Tensions

This chapter also accentuates several conflicting values among participants. These conflicts occur in both broad and specific areas. Broadly, participants value writing highly for its capability to advance knowledge in the field as well as advance individual careers, yet they also have negative attitudes toward the act of putting words on paper. Underneath this general tension lie other, more specific tensions, one of which was mentioned above; while some participants describe the writing process as disjointed and non-linear, others describe the writing process as that which brings order and structure to sets of non-linear technical problem-solving tasks. A contrast related to valuation also arose in Rikard's discussion of the value of writing. On the one hand, Rikard said he was influenced by a mentor early in his career to value oral over written communication. Further, he noted that most engineers do not like to write, find it frustrating, and also may not value it. On the other hand, he made statements that connect with core professional values, saying that unclear writing wastes readers' time (time is money, goal-orientation) and can create misinterpretations among readers (efficiency, utility).

Many factors can help account for these tensions, and one of the most useful is the interrelated set of reasons participants listed for their and their engineering colleagues' negative attitudes toward writing. That is, while experienced engineers recognize the benefits of effective writing for the field and one's career, they also recognize that certain elements, some of which may be specific to engineering, can collectively conspire to create and reinforce negative attitudes toward the act of writing.

Another potentially contributing factor to writing attitudes that was not directly mentioned by participants concerns writing identity. People who write frequently—journalists, novelists, etc.—acknowledge that writing is not a particularly efficient process, and is generally iterative, recursive, often messy, full of stops and starts. If one's self-concept as a writer is already not strong, one could inadvertently ascribe the normal frustrations that writers encounter to one's own lack of ability or facility rather than as common, normal frustrations that serve as opportunities to clarify one's own thinking and to more effectively convey valuable technical knowledge. Another related factor is aptitude, which participants did mention, but not in terms of how aptitude may be reinforcing. That is, if one's cognitive strengths are largely quantitative and scientific, there may be a tendency for one's verbal abilities to be relatively less strong; and as learners, we tend to gravitate toward what we do best and avoid what we do—or perceive that we do—less well, only making strong aptitudes stronger and weak ones weaker. Combined with the lack of practice, especially with writing in their disciplines, and many other factors, engineers' negative attitude toward writing becomes more understandable.

Raising the Bar: The Literacy Ratchet Effect

Despite these attitudes, expectations for writing proficiency are likely on the rise. Byron noted that computers, palm pilots, the Internet, and other technologies are providing more people with more practice in crafting words to convey meaning, so general literacy levels among users of such technologies may be increasing. In addition, a phenomenon I call the literacy ratchet effect may also be slowly and subtlety raising the bar of literacy expectations for engineers. Of all the participants' autobiographical accounts, Illan's most vividly speaks to the complexity of learning to write with confidence, something he did only after years of practice, frustration, experience, and dogged effort. Yet many university faculty expect undergraduate and graduate students to be better writers than they were themselves at those same junctures in their careers. This ratchet effect dawned on me after several years of facilitating writing workshops for engineering and science faculty who are interested in incorporating or re-incorporating writing into their courses. At many of these workshops, I have asked faculty to write informally about what they know now about writing that they did not know when they finished their Ph.D. I compile these responses in a single document that I make available on the second day of the workshop. The document has two columns next to each response, and I ask them to check the first column if they would expect undergraduates to know that particular aspect of writing when they graduate and the second column if graduate students should know that aspect when they graduate. Overwhelmingly, faculty expect more in terms of writing knowledge of the next generation of writing engineers and scientists than they did of themselves. This is a positive phenomenon overall because we should want to bestow on the next generation traits or abilities we did not have but from which we could have benefited.

Yet when faculty *expect* that such outcomes will occur without their involvement or with a single non-disciplinary writing course, the expectation becomes less realistic. Learning to write confidently and effectively is a highly complex feat that requires years of experience, yet we often expect more of younger writers than we ourselves were able to do. Models of the writing process reveal this complexity, which was one of the reasons given for negative attitudes toward writing and merits further discussion because that complexity is sometimes underestimated. Bruning, Schraw, and Ronning (1999) are particularly helpful in framing this discussion on the writing process. For example, the Flower and Hayes Writing Model illustrated in figure 10.1 reveals a complex process. Although only one of many possible models, this model illustrates the fact that writers must tax multiple cognitive resources in the act of writing as they shuttle between long-term memory, where they store content, audience, and writing knowledge, and short-term memory, where they story planning, translating, and reviewing processes, all the while keeping in mind the components of the task environment. Over time, the ratchet effect I mentioned above can gradually raise our expectations to unrealistic levels, which if unchecked lead to disillusionment with the slow but steady results of efforts in writing across the curriculum and writing in the disciplines.

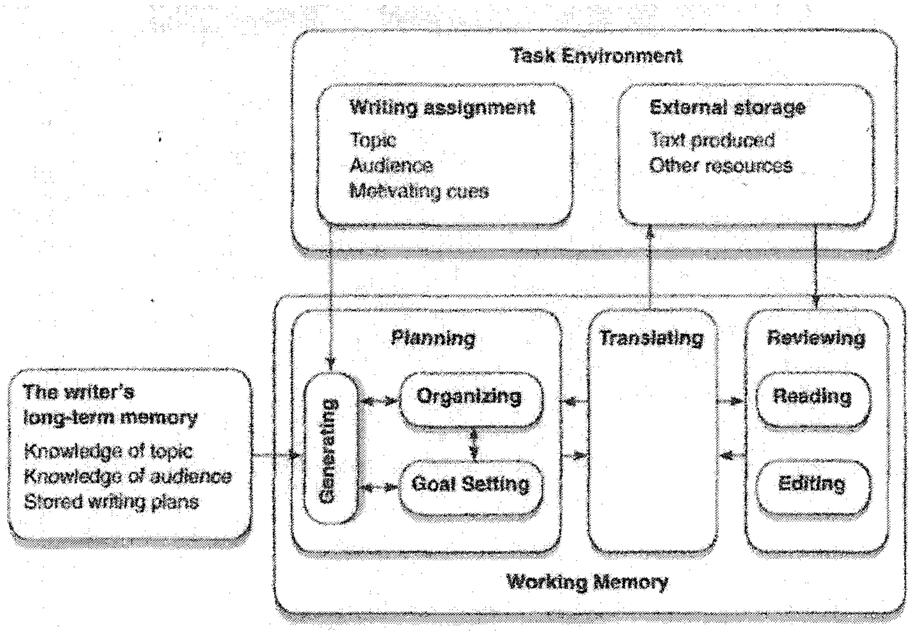

Figure 10.1: The Flower and Hayes Model of the writing process (from Bruning et al., 1999, p. 297; adapted from Gregg & Steinberg, 1980)

That effective writing, despite its complexity, is expected by experienced mining engineers may be driving some of Respondent One's responses to the participants' reasons for writing avoidance. That is, after over 40 years in the profession, Respondent One's early struggles with writing may have long since vanished from memory or may be easier to dismiss since he has already achieved a highly proficient level of professional literacy. It may also be that Respondent One has long been a confident and effective writer and cannot recall being otherwise, so the participant attitudes toward writing seem particularly alien to him. Since the period in which Respondent One inhabited stages one and two on the rhetorical awareness continuum (see Table 8.1) may have been 30, 40, or more years ago, he may have no recollection for such a mindset at this point in his career. In fact, statements emanating from such a mindset may seem quite odd, and this may be why his efforts to make sense of these statements lead him to categorize them as nothing more than "laziness." He may have reached a point in which the value of effective writing skills for the individual and the profession so heavily outweighs any frustration that other mining engineers might experience in the act of writing that these writer frustrations seem trivial by comparison.

Furthermore, Respondent One may inhabit the upper end of the rhetorical awareness continuum. His marginal comments in Chapters 5-10 suggest that he recognizes the complex roles of reader, writer, and data interpreter-spokesperson. For example, when Hugh recounted his surprise at being asked by his internship supervisor to provide a route recommendation, Respondent One replied, "I'm shocked that Hugh did not expect the boss to want a recommendation. After, all he was the one that at that point in time knew the most about the subject and therefore he was being paid to also produce a recommendation!" This and other comments suggest a higher level of rhetorical awareness relative to some other participants.

Information Managers: Engineers as Potential Sense Makers

The complexity of writing in professional contexts is not the only point accentuated by the practicing engineers in this study. For example, Nathaniel, Thomas and Byron indirectly highlighted effective reading skills. According to Nathaniel, Thomas, and Byron, those who are favored for promotion also add value to their organizations by effectively managing and conveying information vertically and horizontally. Given the often overwhelming volume of information in any organization, especially in larger organizations, the ability to organize that mass of data into some logical, coherent whole and suggest actions or directions based on that whole is of great value. Such abilities help bring order to sometimes chaotic, disparate, and ambiguous information, and such "sensemaking" has been correlated with effective leadership (e.g., see Weick, 1995).

Academic Foci and Writing in the Disciplines

Some participants mentioned that the focus of an engineer's academic training is on acquiring skills via quantitative and technical problem solving, and this implies the focus is not on using writing as a problem-solving tool in technical courses, which can contribute to negative attitudes about writing. This academic focus stems in part from a curriculum that is designed to prepare engineers primarily for work in for-profit corporations. As has been noted in a study of disciplinary contexts including engineering and physics (Donald, 2002),

> the prime function of engineering is to generate products and product-oriented techniques, therefore a broader set of skills is expected to be learned than the focused problem-solving skills of physics. (p. 64)

The dearth of writing-to-learn strategies used within many technical courses may also stem from a lack of awareness among engineering faculty that writing can be a powerful problem-solving tool, which may be a result of their own academic backgrounds. While these techniques are taught at the site of this study, they are taught in a humanities course, outside the context that students associate with their professions. However, a small but growing number of faculty at this site regularly employ such techniques in technical courses.

The Role of Disciplinary Context in Attitudes about Writing

Research into the ways in which students in certain disciplines tend to think about knowledge could also be useful in helping to account for engineers' simultaneous value on and desire to avoid writing. That research is best understood in a framework of dimensions on which learners vary in their beliefs about knowledge. Summarizing the work of Schommer (1990), Bruning, Schraw, and Ronning (1999) describe some pivotal beliefs:

> The first dimension, *simple knowledge*, refers to the belief that knowledge is discreet and unambiguous. Students who score high on this dimension believe that learning is equivalent to accumulating a vast amount of factual knowledge in an encyclopedic fashion. Schommer's second dimension, *certain knowledge,* pertains to the belief that knowledge is constant: Once something is believed to be true, it remains true forever. The third dimension is *fixed ability*—that is, the belief that one's ability to learn is inborn and cannot be improved through either effort or strategy use [...]. The final dimension, *quick learning,* refers to the belief that learning occurs quickly or not at all. (p.164)

Among other findings, one study that incorporated these four concepts indicated that students in the social sciences and arts/humanities are less likely than students in engineering and business to believe in certain knowledge. Students in the former disciplines were also found to be more reliant on their independent reasoning ability and have a stronger feeling that learning is not an orderly process. However, students in all four disciplines reported similar views in terms of fixed abilities and quick learning (Jehng, Johnson, & Anderson, 1993). The writing process is often described as chaotic and disorderly, particularly as one is learning new genres and wrestling with new and complex concepts. However, this view is complicated by the fact that a few participants in this study see writing not as chaotic but as providing order and structure to disjointed technical tasks. It is entirely possible that the writing process is both chaotic—at certain points—yet facilitates concept organization at other points. When most or all of the content has been collected and needs to be arranged, as is the case in some of the examples participants provided, writing will most likely be a unifying, clarifying force. However, when information needs to be simultaneously collected, organized and drafted, the process may tend to be more chaotic. In the latter case, that the engineers in the Jehng et al. study expected learning processes to be orderly could lead them to abandon the quest to improve one's writing. Gender may also play a role. All of the participants in this study are male, and other research indicates that females are less likely to believe in quick learning (Schommer, 1994). Such a mindset would likely lead females to lower levels of frustration and greater task persistence, both of which would facilitate the process of learning to become more effective and efficient writers.

However, the two aforementioned studies have potentially contradictory results; the latter study finds that males are more likely to believe in quick learning than females while the former study finds that engineers, who are predominantly male, have views on quick learning that are similar to students in other, less male-dominated majors. It is possible, of course, that male engineering majors are less likely than males in other majors to believe in quick learning, but this finding has not been confirmed or disconfirmed by research. Perhaps one of the most viable contributions of this research in helping to explain why engineers value but have negative views toward writing may be in a cumulative effect: If one is more likely to believe that knowledge is certain and constant over time and that learning processes are generally orderly (Jehng et al., 1993), these beliefs may collectively engender the notions that *writing* is a fixed or innate ability that cannot be improved through effort or by learning new techniques and/or that one learns *writing* (as opposed to learning in general) quickly or not at all. Since data from this study do not directly address, confirm, or negate the possibility of such a cumulative effect, it remains a fruitful area for future research.

Beliefs in certain knowledge and orderly learning—and possibly also fixed ability and quick learning—would need to be dislodged for success in the workplace or in graduate school given the greater exposure to open-ended, ambiguous problems. In fact, as one might expect, research suggests that graduate students are much less likely than undergraduates to believe in certain knowledge or the notions that learning is usually an orderly process and that knowledge is not acquired from independent reasoning. The Jenhg et al. study also suggests that students' epistemological beliefs are at least in part products of disciplinary activities, cultures, and contexts. These researchers define epistemological beliefs as "socially shared intuitions about the nature of knowledge and the nature of learning" (Jenhg et al. 1993, p. 24).

Disciplinary context also has a socializing effect. Given the volume of well-defined problems that engineers encounter and the volume of open-ended problems arts/humanities majors encounter in their diverse disciplinary cultures, the finding that disciplinary training shapes learner's epistemological beliefs may come as no surprise. Of course determining whether students with certain epistemological beliefs tend to be attracted to certain disciplines in the first place could complicate such a finding. However, it is reasonable to assume that both pre-existing beliefs about knowledge and learning *as well as* disciplinary training shape the development of epistemological beliefs.

Of particular relevance to this study is the claim that epistemological beliefs affect cognitive abilities. For example, research indicates that a belief in simple knowledge negatively affects complex problem solving abilities (Schommer, Crouse, & Rhodes, 1992). Other research indicates that individuals with similar beliefs about knowledge tend to reason through diverse types of problems in highly similar ways (Kitchener & King, 1981); this latter study also found a direct correlation between verbal abilities and reasoning ability. Such research may yield some insight into why engineers do not enjoy the complex, relatively open-ended task of writing. However, it is worth noting that the engineers in this study, as noted in the section on PBL, embraced and valued open-ended *technical engineering* problem solving. Their definition of problem-solving, however, does not always include writing as a primary tool, even though they recognize the value of using that tool. Although many of the statements of the students interviewed in this study were less complex and at times more contradictory than the statements of other participants, such statements do not yield sufficient evidence to determine whether the two students' epistemological beliefs match the results in any of the aforementioned research. The primary purpose of this study was not to pinpoint epistemological beliefs and explore their relationship to writing attitudes, although this is a worthy topic for future investigations.

The above discussion also opens another door to inquiry. If research suggests that disciplinary training has a shaping effect on one's epistemological and cognitive abilities, science majors might be in the same situation as engineering majors concerning the difficulty in translating ideas from visual media to words. Like engineering, science contains multiple abstract concepts that are more efficiently learned and remembered in visual form. In fact, many engineering principles are or are based on scientific principles. However, one tangentially relevant study and a general lack of research in this area make comparisons between science and engineering majors difficult. Results of one study indicate that science majors are *less* likely than education majors to believe in certain knowledge or quick learning (Schommer, 1991). Research comparing humanities, science, and engineering majors' epistemological beliefs and reasoning abilities would be quite useful in exploring this question, but to date little has been done in this area.

Translating Visual Concepts into Words

A similar gap exists in the literature on translating visual concepts into words. Much research has been done on the utility of using visual imagery to represent concepts that are described in words, a process that facilitates learning and remembering (Goetz, Sadoski, Fatemi, & Bush, 1994; Sadoski, Goetz, & Avila, 1995). However, relatively little has been done on the opposite process. While participants in this study emphasized the difficulty and importance of learning how to translate visual/technical concepts into words, scant specifics were mentioned or are available in the literature on the processes by which such an ability develops. Reading the documents penned by engineers who are experienced in translating visual/technical concepts into words is probably one of the ways this learning occurs, and some of the participants in this study noted benefits from reading workplace documents, although their notions of what exactly they learned from that task were not elaborate and may be largely tacit.

Existing literature is helpful, however, in creating a conceptual framework in which visual and verbal learning can be better understood. As mentioned in Chapter 9, the dual coding theory holds that we mentally represent information in two distinct coding systems—verbal and imaginal. Although an oversimplification, coding information refers to the process of putting information into a form we can understand and remember. We use verbal representation when thinking about words, sentences, and other experiences stored in our verbal coding system, and we use our imaginal coding system to store nonverbal information such as pictures (Paivio, Clark, & Lambert, 1988). Although the two systems are distinct, research also suggests that information coded in only one of these two systems is not remembered as well as information coded in both (Paivio, 1986). Other research indicates that nonverbal information tends to be recalled more readily because we often put a label to pictures and other imaginal information—that is, we double code—but we do not necessarily image verbal information (Paivio, 1986; Svengas & Johnson, 1988). In the context of the present study, engineers' challenge is not always transferring ideas from imaginal to verbal, since they generally have labels for visual images. Rather, the translation process of communicating with non-technical audiences involves two phases: from image to technical terms to lay language. The complexity of this process may stem from the fact that the final translation is not once but twice removed from the engineers' original visual-technical representation. The process could be analogous to translating a concept from a Chinese character to a precise but obscure English word and then to other, more accessible language that described the meaning of that obscure English word. This analogy can also be reframed to illustrate the complexity of translating concepts between imaginal and verbal systems. For example, the Chinese character for hand, when added to the character for hole, means dig. This idea that "hand + hole = dig" is all represented visually, or pictorially, whereas the word dig in English is composed of three letters in sequence—a completely different way of representing the same concept. As an intriguing aside, this same combination of Chinese characters also translates as excavate and gouge. By contrast, in Italian, one word for dig is *scavare,* which, thanks to shared Latin roots, is similar to the English word excavate. The degree of complexity in translating from visual to verbal becomes more apparent in contrasting the process by which one would translate from Chinese characters into English words vs. from Italian words into English words. In the case of translating from Chinese to English, one must cross a gulf between visual and verbal representation, whereas in translating from Italian to English, no such chasm must be crossed; however, a large lexicon is required for accuracy in the latter translation. This analogy may help explain the complexity inherent in the two-phase translation from image to technical terminology to lay language.

A Later Developmental Phase: Decreasing Avoidance, Increasing Comfort

The tendency among participants in this study suggests that the younger, less experienced members of the profession place more emphasis on the desire to avoid and the discomfort in performing the act of writing than on the value of writing. So at first, displeasure seems to outweigh value, contributing to relatively more negative attitudes about writing. However, once the participants reach a certain stage in their writing development, as did Byron and Illan, gradually displeasure diminishes while their recognition of the value of writing seems to increase. Byron and Illan do not describe themselves as experiencing discomfort while writing; in fact, Illan describes a level of comfort. Thus, these later stages seem to be characterized by decreasing discomfort, increasing comfort, and increasing confidence with the writing task and, as both Byron and Illan noted, an increasing recognition of the value of writing. Although not a participant, Respondent One's views also seem to most closely correspond with characteristics of this later stage. Further, Byron, Illan, and Thomas (as well as Respondent One) describe writing as not separate from but integral to effective engineering practice. In short, some engineers do not dislike writing forever.

Implications for Practice

The engineers in this study have provided snapshots of perceptions at different career stages, and those perceptions are in part a function of their current career exigencies. If mentors can play a role in shaping negative attitudes toward writing, then they can also play a role in fostering positive ones as well. But mentors come with diverse ways of knowing and thinking. One can see, for example, how Illan and Rikard's different life and career experiences with writing has made one wholeheartedly committed to writing in the disciplines as an important platform for effective writing in the profession while the other pays it only passing notice, describing writing as merely students' "communication tool." Leaders of writing in the disciplines initiatives have their work cut out for them. Illan's voluntary participation a few years ago in a workshop for faculty who teach writing-intensive technical courses was motivated by his interest in and commitment to teaching writing as an important engineering skill. Yet those participants are self-selected, and as most university faculty know, faculty can be forced to do little; when they are, dramatic results cannot be expected. However, the more faculty like Illan and engineering practitioners like Byron, the more young engineers will be exposed to mentors who see that writing is an essential component of effective engineering practice.

References

Bruning, R. H., Schraw, G. J., & Ronning, R. R. (1999). Writing. In *Cognitive psychology and instruction* (3rd ed., pp. 295-319). Upper Saddle River, NJ: Prentice Hall.

Donald, J. G. (2002). *Learning to think: Disciplinary perspectives*. San Francisco: Jossey-Bass.

Goetz, E. T., Sadoski, M., Fatemi, Z., & Bush, R. (1994). That's news to me: Readers' responses to brief newspaper articles. *Journal of Reading Behavior, 26*, 125-138.

Gregg, L. W., & Steinberg, E. R. (1980). *Cognitive Processes in Writing*. Mahwaw, NJ: Erlbaum.

Jehng, J. J., Johnson, S. D., & Anderson, R. C. (1993). Schooling and students' epistemological beliefs about learning. *Contemporary Educational Psychology, 18*, 23-35.

Kitchener, K. S., & King, P. A. (1981). Reflective judgment: Concepts of justification and their relationship to age and education. *Journal of Applied Developmental Psychology, 2*, 89-116.

Paivio, A. (1986). Dual coding and episodic memory: Subjective and objective sources of memory trace components. In F. Klix & H. Hafgendorf (Eds.), *Human memory and cognitive capabilities: Mechanisms and performances* (pp. Part A, pp. 225-236). Amsterdam: North-Holland.

Paivio, A., Clark, J. M., & Lambert, W. E. (1988). Bilingual dual-coding theory and semantic repetition effect on recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 163-172.

Sadoski, M., Goetz, E. T., & Avila, E. (1995). Concreteness effects in text recall: Dual coding or context availability? *Reading Research Quarterly, 30*, 278-288.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*, 498-504.

Schommer, M. (1991, April). *The relationship between students' beliefs about the nature of knowledge and academic experiences.* Paper presented at the Annual Meeting of the Midwestern Educational Research Association, Chicago.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review, 6*, 293-320.

Schommer, M., Crouse, A., & Rhodes, N. (1992). Epistemological beliefs and mathematical text comprehension: Believing it is simple does not make it so. *Journal of Educational Psychology, 84*, 435-443.

Svengas, A. G., & Johnson, M. K. (1988). Qualitative effects of rehearsal on memories for perceived and imagined complex events. *Journal of Experimental Psychology: Educational Psychologist, 24*, 113-142.

Weick, K. E. (1995). *Sensemaking in organizations*. Thousand Oaks, CA: Sage.

CHAPTER 11: DISCUSSION

This discussion of the findings and analyses in Chapters 5-10 is guided by an inquiry into what has emerged about the phenomenon of writing in this capstone SD course and in participants' various contexts that was not apparent or known prior to the study. Such an overview begins with the voices of Respondents Two and Three, who read the findings (without the researcher commentaries) in Chapters 5-10. Unlike Respondent One, who provided comments within the text of the findings, the other two provided summary comments, which appear below.

Respondent Two

"[Summarizing my questions to her:] What parts of the study most resonated as true in your experience as an engineer/TC person? What aspects of the study may have seemed particularly accurate (or inaccurate, if applicable)?

- *" The results represented in this study resonated with me on multiple levels. As an educator within both engineering and technical communication, I resonated with the developmental nature of the results, seeing how the ideas evolved across the different subject groups - from undergrad to employee to client and instructor. I also resonated with the result concerning the complicated nature of audience as it applies to the senior design reports.*

- *" As an engineer and a technical communicator within engineering, I resonated with the overall variability of the results and the image of engineers as diverse in their perspectives on writing. In particular, I resonated with their ability to identify various genres of engineering writing (including email), the importance of audience in engineering writing, the link between persuasion and brevity, and the importance of visual communication in engineering.*
- *"One result that made me pause was the result having to do with the amount of time various participants said that they spent writing (e.g., [...] 10%, 15%). This does not seem consistent with my observations of and discussions with engineers. At the same time, I wonder if this stems from a mismatch concerning what counts as writing (i.e., I count more activities as "writing" than other engineers would). There were clearly hints in the results concerning what the participants count as writing (writing of emails, memos, etc.). The discussion of their views of diagrams and tables suggested that they had different opinions about whether "writing" involved creating those representations.*

"[Reiterating my question:] Any implications/utility the findings might have for your teaching? For teaching in engineering education?

- *" As a researcher who firmly appreciates empirical work and an engineering educator interested in change in engineering education, I think there is incredible utility to having research that records these findings, particularly in the specific context of engineering education. I also liked how your different sections collectively present a multi-faceted image of writing. To help the engineering education* *community realize this utility, I couldn't help but wonder what type of representations could serve to summarize these findings.*

- *"Moving a bit more local, I think this type of information could be incredibly valuable to technical communication educators in helping them understand where their students may start and where they may end and what they will still need to learn when they get into the "real world" (in other words, helping TC educators understand their audience even better). Further, having the findings represented by individual means that these individuals can be used loosely as a way to characterize the students coming into our classes. In a way, the characters in your research could be treated as personas and we could imagine the impact of our classes on such personas.*
- *"At a more immediate level, the results have me thinking about the complex issues of audience associated with writing that students do within engineering education (as illustrated by the senior design report)."*

Respondent Three

"FEEDBACK 1: [Summarizing my questions to him:] Do these findings ring true for you as an engineer? Are they consistent with your experiences? In what ways are they consistent or inconsistent?

"Conclusion. Very strong alignment with my past experience. My rationale is listed below.

[...]

1. *The many quotes from students and practioners are highly reflective of the student and professional voices that I have heard. In particular, the strong emphasis on the*

practical, the technical, the visual, and the value of oral communication is highly reflective of my past experience.

2. *Most professionals strongly value the completed final report as a way of creating an archival documentation of a project.*
3. *I have found that students are often oppositional to writing if it is presented as an 'out of context' assignment. When I present the writing as part of an engineering task, this disconnect goes away dramatically. This aligns with your finding that engineers value writing as a disciplinary task.*
4. *I have found that most students and many professionals write after a project is over (we call this backfilling). They do not structure their engineering work with writing that is performed concomitant with the project. Comment: This misses the major advantage of writing, which is to use writing as a scaffold to guide your thinking before and as you do your engineering. Writing without multiple drafts is incredibly hard. This aligns with your findings of "writing induces fear" and "viewing writing as tangential."*
5. *I have found that most students and professionals think of writing as a tangential activity; that is, it is not part of engineering problem solving. Comment: My viewpoint--with metacognitive practice, most engineering activities done with pencil & paper are strongly aligned with writing. That is, when we are writing things down on paper, we are always telling a story (just like in writing). Because engineers are practical, we use many shortcuts: math symbols are a short hand way of writing words. Sketches are a way of writing on paper what one sees in ones' head (or of teaching your mind to see).*

"FEEDBACK 2: [...] My interpretation of your findings is this: Engineers (both students and practioners) recognize the value of writing in a variety of ways: as a means of promoting thinking, as a way to get recognized in an organization, as a way of creating documentation. However, they do not use writing as effectively as they might be able to. The reason is that they have not yet developed the practice and skills of using writing as a means to more effectively execute engineering projects. That is, this research suggests that improvements in both engineering practice and writing can be made by teaching writing integrated with professional practice as a means to elevate practice. To attain this outcome, engineering professors will need to help students learn how to use writing as a way of problem solving. Moreover, we need to help students learn how to integrate visual, verbal and mathematical representations as a way of writing. [Relevant Theoretical Frameworks include:]

1. *The Writing to Learn [WTL] framework (writing is means of problem solving; engineering features problem solving).*
2. *The ABET criteria emphasizes communication.*
3. *The assessment framework (see Pelegrino et al. "Knowing What Students Know") places a major emphasis on metacognition in problem solving. Writing is a very powerful tool for practice of metacognition.*
4. *Overall, I think the best framework is WTL, probably the work of Bean.*
5. *Overall, I think your work provides evidence of the need to incorporate extensive WTL into engineering education."*

In combination with the comments of Respondent One, these two sets of responses augment the overall trustworthiness of the study and give thoughtful suggestions for practical applications of the findings.

Respondent Two accentuated the developmental nature of the findings, which give educators clues about where "students may start and where they may end and what they will still need to learn […]." In that spirit, it may be useful to look at select findings through a developmental lens to appreciate the range of participant perspectives. Table 11.1 explores part of what we know about the phenomenon of writing in this capstone SD course and in participants' various contexts now that we have heard the multi-faceted participant perspectives. This table also clearly represents an oversimplification of select findings from this study, and perhaps therein lies a clash between disciplinary cultures, one that values concise and often visual data summaries for increased ease of use and the other that values rich and often verbal data narratives to capture as much complexity as possible. Table 11.1, then, amounts to a compromise.

Table 11.1: An Overview of Various Participant Perspectives on Select Issues

Characteristic (Chapter Reference)	College Seniors in Engineering	Practicing Engineers	Experienced, Reflective Engineering Practitioners
Participants' way of valuing the act of solving real, open-ended problems via PBL. (Chapter 5, Senior Design—The Capstone Experience)	Value learning by doing, practical, real over hypothetical or contrived problems; however, balance between PBL experiences and high content courses is desirable.	Although there is no working preparation better than working, PBL courses have excellent preparatory value.	For academic contexts, PBL courses most closely resemble actual engineering practice, especially when companies may use students' solutions; a higher quality PBL experience is desirable (e.g., via more student-advisor and student-client interaction, project

			management training, etc.)
Perspective on the relationship between writing and socialization. (Chapter 6, Socialization)	Writing plays no socializing role.	Along with other factors, writing plays a limited role in socialization.	Writing plays a limited socializing role along with many other factors, and writing also reveals one's degree of socialization into an organization.
Understanding of the exigencies of workplace writing. (Chapter 7, Workplace Writing)	Participants describe mostly surface characteristics of various workplace genres and some discipline-specific writing traits.	Participants commented on workplace expectations such as length, concision, and precision.	Participants described what constitutes effective workplace writing, including specifics on problem representation, tone, voice, coherence, audience, and purpose.
Importance of rhetoric in professional written communication (Chapter 8, Rhetoric)	Denial mixed with acknowledgement of the relevance or importance of rhetoric.	Various degrees of acknowledgement of the importance of rhetoric.	Emphasis placed on the importance of rhetoric for successful *engineering* practice.
Role of writing in technical problem solving (Chapter 9, Writing and Thinking)	Writing is a tool for communicating technical ideas; writing can be a tool for learning.	Writing is a useful learning tool.	Writing can facilitate learning at particular junctures in the technical problem-solving process.
Attitudes about and values on writing (Chapter 10, The Value of Writing)	The reasons for negative attitudes toward writing tend to outweigh the value of writing for the individual.	The value of writing and reasons for negative attitudes tend to compete for dominance.	The value of writing for the individual and for the profession outweighs the reasons for writing avoidance, which are recognized and often transcended.

In addition to this overview of select findings, it may also be useful to look at an overview of participant comments on writing in general, as participants in various career stages and organizational roles have provided glimpses into how engineers' mental representations of writing develop over time. Ideas on the lower end of the spectrum in Table 11.2 generally emanate from participants with relatively less career experience or those who have reflected less on writing conceptions while upper-end ideas often came from participants with relatively more career experience, in leadership roles, or those who had more elaborate reflections on writing conceptions.

Table 11.2: Developmental Spectrum of Engineers' Conceptions of Writing

Low End of the Spectrum	Upper End of the Spectrum
Writing is extraneous to engineering problem-solving processes.	Writing is integral to engineering problem-solving processes.
Engineering thinking occurs in pictures, so writing is not relevant to solving problems.	Engineering thinking involves significant visual components and some writing.
The act of writing occurs after the technical problem has already been solved.	The act of writing deepens one's technical content knowledge and can occur before, during, and after problem solving.
Lay and non-engineers have difficulty understanding technical visual data.	Translating technical ideas for lay or non-engineering audiences is difficult but vital.
Writing is to be avoided.	Translating technical visual data into a language that non-engineers can understand is often the way an idea becomes reality.
Writing is a necessary evil, and I hope to not have to do much of it.	Effective writing skills do not hurt promotion; ineffective ones can prevent it.
Some writing is persuasive but some of it is purely factual.	In addition to informing others, the primary reason we write is to influence & persuade.

Intersections between this Study and Existing Literature

In addition to adding the findings sketched in Tables 11.1, 11.2, and all other findings to the body of knowledge, this study has also intersected with existing literature in multiple ways. For example, literature on writing in the engineering discipline has underscored the value of writing skills for success in the workplace, via interviews with and surveys of practicing engineers (Benefield, Trentham, Khodadadi, & Walker, 1997; Katz, 1993; Vest, Long, & Anderson, 1996; Vest, Long, Thomas, & Palmquist, 1995). This study expands our understanding of how career stages and organizational roles shape the valuation of writing skills; specifically, we see different valuations among college seniors than among practicing engineers, and among practicing engineers in non-leadership roles vs. those in leadership roles.

Respondent Two's concern about participants' self-reported percentages of time spent writing deserves some comment. As noted in Chapter 2, a review of studies indicates that 20-40% of a typical engineer's workday is spent writing, a figure that climbs as one moves up the career ladder (Kreth, 2000). Another study indicates that in their first few years on the job, engineers spend roughly 30% of their workday writing while engineers in middle management write for 50-70% of their day; also, those in senior management spend over 70% and as much as 95% of their day writing (Silyn-Roberts, 1998). By contrast, the engineers' self-reported percentage estimates in this study ranged from a low of 3-5% to a high of 15-20%. This may imply that mining engineers write less than other types of engineers, that they are not fully conscious of how much time they actually spend writing, or that their definitions of what constitutes writing may vary and thus render murky any self-reports. But such generalizations should not be made from such a small sample size (only three participants articulated a clear percentage estimate, and even eight estimates would be too few). What is remarkable, however, was that participants who articulated percentages that were lower than averages reported in the literature qualified their comments; they said that the writing they do, although it may occupy only a small portion of each day, matters much to the organization. For example, two participants indicated that their writing is often an extension of their role as organizational change agents and tends to be quite strategic.

This study also expands Winsor's insightful longitudinal study on engineering writers by beginning from the point at which her initial study on four undergraduate engineering students ends (Winsor, 1996). Participant comments in this study confirm the notion that in complex ways college seniors deny the importance and/or relevance of rhetoric; this study also suggests that this denial among college seniors occurs at the same time that they acknowledge the relevance of rhetoric. Further, Winsor's notion of the clash between the denial of rhetoric and the role rhetoric plays in engineering practice surfaces in this study in new ways. For example, a striking contrast exists between the two college seniors' notions of the importance of rhetoric and all other participants. Again, career stage and organizational role have shaping influences on the degree to which participants are apt to acknowledge the importance of rhetoric as a component in successful engineering practice. Such evidence suggests that a rhetorical focus in teaching writing in engineering disciplines would be beneficial, but probably only if students first recognize the price of denying rhetorical influences and the advantages of acknowledging them. However, such a shift may require students to re-see the (arguably limited) scientific and technological paradigm they may have constructed; beyond that view of the paradigm, notions of scientific objectivity may be maintained as an ideal and tempered by realistic assessments of the nature and complexity of human decision-making in technical contexts. This complexity may be best conveyed when grounded in actual engineering case studies, which can highlight rhetorical complexity. Research shows gains in students' rhetorical knowledge when rhetorical topics have been explicitly taught in the context of engineering courses (Maharaj, 1994; Ramey, 1999; Walker, 1999), and case study methods are fairly commonplace in technical communication education.

The findings of this study regarding participant conceptions of rhetoric expand beyond the literature surveyed by constituting a call for ethics. Table 8.1, a continuum of rhetorical awareness, brings to the fore the ease with which those holding stage 1 or 2 views can be manipulated, perhaps at high cost to their own careers and to their employers. As mentioned in Chapter 8, the intentional selection and omission of data, whether to support a hidden agenda or weakness in a product or service, can significantly shape the perspectives of audiences, even in the case of quantitative data. Engineers who deny the importance of audience and think data speak for themselves deny the complex role of the data spokesperson(s) as well as the human contexts in which all engineering occurs. In doing so, such engineers become more vulnerable to manipulation and to involvement in safety and legal disputes. By contrast, those at higher stages on the rhetorical continuum display greater degrees of tolerance for ambiguity and of awareness for the role of the data narrator in creating what counts as knowledge. To work effectively, engineers and their colleagues need to be able to trust that those who present data portray the whole picture ethically rather than a selective spin that only foregrounds conclusions consistent with a preexisting agenda.

To expand this discussion in the context of this study, it may be useful to contrast two participant comments that suggest a kind of fascination with a (perhaps newly acquired) rhetorical trick with the perspective or Respondent One, who focuses attention on the broader arena in which such tricks operate. Nathaniel indicated that in meetings with non-engineers, he sometimes consciously turns the topic to technical matters:

> [...] even if what I am talking about is borderline nonsense, the more technical I get, your accountants and lawyers become uncomfortable because they don't

> know what you are talking about. And especially lawyers [...] they will never admit or ask questions [if] they don't know something. They [...] will scurry away from the topic and let you have your way [...]. This is a tactic that I have used repeatedly, and it works very well.

Furthermore, in Thomas' account of persuasion, he noted that

> [...] if you really want to be effective in persuasion, they can't know that that's what you're doing. When you get up and do a presentation, that's much more difficult to conceal, but in writing it's much easier. You can persuade someone in writing and lead them to the conclusion that you want them to get, without them ever really know what you are doing.

To Nathaniel's comment, Respondent One replied, "It doesn't matter if the lawyers understand it or not, persuasive documents must be written for many, many reasons."

Other comments from Respondent One help explain his perspective:

> [...] If the client does not understand the technical aspects of the report, he can always ask for an explanation of what he does not understand. But if something critical is omitted or glossed over because it is too technical to understand, then he will not ever know anything about the problem and may find out after the plant or mine is built. At that point, the persons who did the study are legally and financially liable for what the client was not told because it was too technical. It is permissible to place some lengthy, technical calculation in the appendix to keep the main report somewhat concise. As to writing it for the future lender, I guarantee you that every bank or lending agency has qualified technical people that will be examining the feasibility report.

At another juncture, Respondent One also said that

> [...] If all the readers interpret your writing as conveying some things that are not really quite as good as you portrayed them, then guess what; after the facts are revealed, a jury may very well convict you of a libelous act and there goes your house. The same is true of simply not reporting something that is negative [...]. This brings up a good point: every SD course should contain at least one lesson on Ethics and Liabilities related to performing feasibility and evaluation type of work. The student needs to know, if he is working as a consultant after graduation on this type of work, he is indeed liable and he may indeed be betting his house on the report's accuracy.

Such comments put rhetorical tricks into a new perspective; Respondent One reminds us that engineering decisions are embedded within larger social, political, environmental, economic, ethical, and legal contexts. Countering Rikard's notion that the bottom line is the primary driver in mining engineering decisions, Respondent One said, "I think that Rikard is forgetting that in today's society, safety, environmental issues and sustainable development are issues on management's mind just as much as which cost less. Which solution will keep them out of trouble and in the good graces of the public may be more important than the direct cost." These comments again underscore the need for ethics and the value of knowing one can trust one's colleagues.

However, achieving such trust is further complicated by the fact that we often consciously or unconsciously tend to select and present information that is consistent with our own perspectives and ideological stances, and deciding whether selection or omission of data was a legitimate oversight or intentional deception is not always straightforward. In such circumstances, people often rely on past interactions and the degree of trust equity that has accumulated. Consistent ethical behavior in the past, or the perception thereof, will mean greater degrees of trust equity. However, at this point, we are launching into areas richly textured with ambiguity. Issues of perception, reality, interpretation, and miscommunication are perhaps as far from exact sciences as one can imagine, and rather than dwell within such chaotic and ambiguous realms, some prefer the relatively comforting sanctuary of the definite and absolute. This is not to imply the nonexistence of absolutes, but to suggest that ambiguity is often, for various complex reasons that are beyond the scope of this discussion, met with denial. Perhaps via instructor or employer first-hand testimonial and case study, young and apprentice engineers can better recognize the potential costs of denying rhetoric, the potential benefits of ethical actions, as well as the notion that open-ended, ambiguous problems are often the norm in engineering practice.

Tolerance for ambiguity is also a subtle but important recurring theme in participant comments in this study. In fact, the developmental progression that has emerged from participant comments suggests a gradually increasing tolerance for ambiguity from college seniors to more experienced, reflective engineering practitioners, especially as demonstrated by Tables 8.1, 11.1, and 11.2. The finding that tolerance for ambiguity gradually increases over time and via education and reflection concurs with other developmental research in terms of beliefs about knowledge (Belenky, 1986; Perry, 1970; Schommer, 1994), of intellectual and ethical beliefs (Gilligan, 1982; Kohlberg, 1963), and of reflective judgment, which examines how people solve problems (King & Kitchener, 1994; Kitchener & King, 1981). Future research might explore intersections among the growing tolerance for ambiguity relative to rhetorical issues in light of these or other developmental research concepts. Since this study featured only European or Euro-American male participants, it would be valuable to contrast the findings in this and similar studies with findings from studies with female-only and mixed gender participants, participants with a variety of ethnic backgrounds, as well as participants whose socioeconomic backgrounds are factored in. Also, future research could examine the initial sketches of the developmental continua described in this research to expand our understanding of how engineers evolve in their thinking about writing over the span of their careers.

Respondent Two also found intriguing issues of audience in SD. One study has shown that writing can play a vital role, along side discussion and visual representation of data, in the process of teaching and learning engineering design (Lewis, 1999). The present study highlights a potentially fruitful intersection among instruction in design, writing, and visual information processing, as all involve process-product connections as well as stages involving invention or information gathering, organization or shaping, as well as implementing ideas culled in the invention and shaping stages. That is, design courses represent particularly fertile ground for learning how design, writing, and visual knowledge can work in concert for effective problem solving. When SD involves industry clients with actual projects, SD instructors also have a rare opportunity to help students understand the needs of diverse audiences, the role of organizational context in document design, and the role of explicit and implicit purposes driving SD reports. Regarding organizational context, SD represents a unique opportunity for SD students to better understand how to transcend the one-size-fits-all approach to writing for various audiences. Some research indicates that engineering students often fail to make distinctions between engineering genres (e.g., lab reports written in the same manner as proposals). That same study also noted that engineering students did not recognize the role of writing in articulating information more effectively, organizing ideas, visualizing thinking, communicating at a distance, presenting a finished product, gaining understanding, or informing their audience (Mathison, 2000). For SD instructors to understand how these elements may function and how students can benefit by reflecting on them, they may want to collaborate with writing faculty.

Also, design and especially SD courses provide rare chances to address issues unearthed by this research. Under "Feedback 1," Respondent Three noted three issues (points 3-5) that merit further discussion. He said that in his experience, engineers are less resistant to writing when it is embedded within engineering tasks and that most students and many professional engineers "backfill" by writing only after project completion and not during the process of problem solving, effectively limiting their problem-solving efficiency. He also mentioned that most students and many professionals conceptualize writing as extraneous rather than integral to engineering problem solving. He added that with metacognitive practice, students may realize how engineering activities are aligned with writing activities. I agree with Respondent Three that this research suggests that "improvements in both engineering practice and writing can be made by teaching writing integrated with professional practice as a means to elevate practice." Research from writing in the disciplines also reinforces the importance of such instruction. Because writing expectations tend to be shaped by a discipline, and because much of what experienced writers know about writing is often tacit, it makes sense that such tacit knowledge be communicated at least in part via apprenticeship (*Premises of writing in the disciplines*, 2003). Studies like this one also provide value in making that tacit knowledge more overt for readers and in accentuating the value writing scholars might hold in providing engineering faculty with tools to make their tacit disciplinary writing knowledge more overt, so they can be more aware of student misconceptions about disciplinary writing.

Limitations of Findings and Areas for Future Inquiry

While quantitative studies provide breadth, covering larger sample sizes, qualitative studies provide depth—rich, detailed descriptions of participant perspectives. The relatively smaller sample sizes in qualitative studies mean that broad generalizations should not be made to large populations. However, if conditions in one context closely resemble those in the study site context, we can speak about the transferability of the implications of certain findings. Thus, the degree to which these findings extend beyond this study depends on the degree to which other engineers and engineering educators find themselves in circumstances similar to the study participants.

For those interested in generalizability, this study can serve as a baseline for further inquiry. In addition to ideas mentioned in Chapters 5-10, future research may, for example, investigate via survey research the degree to which the reasons listed for writing attitudes extend to larger sample sizes. Mixed method studies could also emerge from this research. For example, survey researchers might explore whether engineers say they use writing in engineering problem solving and to what degree, and then observe a sampling of the same engineers to see how they actually use writing in everyday engineering practice. Further, the findings listed in Table 11.1 could all be explored in a vast variety of ways to see how such findings interface with findings in engineering subdisciplines other than mining and to other, non-engineering disciplines. Future research might also continue to explore how individual and disciplinary values as well as writer identities shape conceptions of writing and rhetoric. Finally, insights could also come from placing findings from this study in conceptual frameworks such as genre or activity theory.

References

Belenky, M. F. (1986). *Women's ways of knowing: The development of self, voice, and mind.* New York: Basic Books.

Benefield, L. D., Trentham, L. L., Khodadadi, K., & Walker, W. F. (1997). Quality Improvement in a College of Engineering Instructional Program. *Journal of Engineering Education, 86*(1), 57-64.

Gilligan, C. (1982). *In a different voice: Psychological theory and women's development.* Cambridge, MA: Harvard University Press.

Katz, S. M. (1993). The entry-level engineer: Problems in transition from student to professional. *Journal of Engineering Education, 82*(2), 171-174.

King, P. A., & Kitchener, K. S. (1994). *Developing reflective judgment.* San Francisco: Jossey-Bass.

Kitchener, K. S., & King, P. A. (1981). Reflective judgment: Concepts of justification and their relationship to age and education. *Journal of Applied Developmental Psychology, 2*, 89-116.

Kohlberg, L. (1963). The development of children's orientation toward moral order: Sequence in the development of moral thought. *Vita Humana, 6*, 11-33.

Kreth, M. L. (2000). A survey of the co-op writing experiences of recent engineering graduates. *Professional Communication, IEEE Transactions on, 43*(2), 137-152.

Lewis, B. J. (1999). Talking to Text and Sketches: The Function of Written and Graphic Mediation in Mechanical Engineering Design (Writing across the Curriculum, Technical Writing, Rhetorical Invention). *DAI, 60*(04A), 332.

Maharaj, S. (1994). A Case for Writing to Learn in the Engineering Curriculum. *DAI*, 300.

Mathison, M. (2000). "I don't have to argue my design--the visual speaks for itself": A case study of mediated activity in an introductory mechanical engineering course. In R. Andrews (Ed.), *Learning to argue in higher education* (pp. 74-84). Portsmouth, NH: Boynton/Cook.

Perry, W. G. (1970). *Forms of Intellectual and Ethical Development in the College Years: A Scheme.* New York: Holt, Rinehart, and Winston.

Premises of writing in the disciplines. (2003). Retrieved August 5, 2003, from http://www.engl.niu.edu/wac/

Ramey, D. E. (1999). Assessing writing instruction in a sophomore engineering course: Iterations of integrating writing from 1995--1999. *DAI, 60*(12A), 192.

Schommer, M. (1994). Synthesizing epistemological belief research: Tentative understandings and provocative confusions. *Educational Psychology Review, 6*, 293-320.

Silyn-Roberts, H. (1998). Using Engineers' Characteristics to Improve Report Writing Instruction. *Journal of Professional Issues in Engineering Education and Practice, 124*(1), 12-16.

Vest, D., Long, M., & Anderson, T. (1996). Electrical engineers' perceptions of communication training and their recommendations for curricular change: results of a national survey. *Professional Communication, IEEE Transactions on, 39*(1), 38-42.

Vest, D., Long, M., Thomas, L., & Palmquist, M. E. (1995). Relating communication training to workplace requirements: the perspective of new engineers. *Professional Communication, IEEE Transactions on, 38*(1), 11-17.
Walker, K. (1999). Using genre theory to teach students engineering lab report writing: a collaborative approach. *Professional Communication, IEEE Transactions on, 42*(1), 12-19.
Winsor, D. A. (1996). *Writing Like an Engineer: A Rhetorical Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

APPENDIX A: INSTRUCTOR INTERVIEW QUESTIONS

Note: In no interview were all the questions listed here asked of participants; rather, these questions served as a general guide and reference point during each interview.

Opening Questions

Tell me briefly about your own professional background.

- Could you tell me about the kinds of writing you do for your job?

Tell me about your role and experiences with Senior Design.

- Could you tell me what students should ideally know and be able to do when they finish this course. [That is, tell me about its overall objectives.]
- We've talked about some of the course objectives. Could you tell me more about the course objectives in terms of written communication.
- Could you tell me about ways in which Senior Design is perhaps similar to yet different from other courses in the ME curriculum?
- From your viewpoint, what are some of the chief advantages of the course?
- Tell me about the writing assignments.

Could you walk me through the process by which students arrive at the end of the course having met the objectives of Senior Design?

Could you tell me about the process of bringing student writing from looking like average first-year college students' writing to a point where they can write more like practicing engineers (this is through Senior Design and any other courses they would encounter in ME)?

The Socialization Dilemma/The Newcomer Dilemma

Could you walk me through the process by which someone goes from being an "outsider" to being an insider in the field of ME?

That is, I'm interested in the process in which newcomers to the field gradually shed their newcomer status and become accepted members of the field?

Could you tell me what role writing plays in the process of socializing someone into the field of mining engineering?

Knowledge Conceptions Dilemma

Could you tell me in what ways the way students thinking about knowledge* is different from or similar to their instructors and clients?

How could this affect their performance in SD? *lots of possible conceptions of knowledge—e.g., static vs. dynamic.

Could you talk to me about what characteristics distinguish the more experienced writers from the less experienced writers?

Could you tell me whether you think there is a link between less and more experienced writers and students who see knowledge as static or dynamic?

Could you tell me how students generally use writing—that is, what practical purposes it serves for them in SD?

The Rhetorical Dilemma

Could you comment on the role audience* plays in the writing students do in SD? Could you comment on the role persuasion** plays in the writing students do in SD? *Audience here refers to the person(s) to whom the writer is writing.
*Persuasion can include anything from persuading someone how a particular design meets set criteria to why a project should be funded to why a procedure is unsafe.

We've talked about persuasion in SD. Could you tell me what role persuasion plays in ME writing generally?

Could you tell me what role writing in SD plays in developing higher-order thinking skills (e.g., application, synthesis, and evaluation)?

What role(s) does the writing play in helping students understand what constitutes effective writing in Mining Engineering?

What role(s) does the writing play in helping students understand what constitutes effective writing in the workplace?

Closing Overview Questions

What feedback have you received about this course from past or present clients?

What feedback have you received about this course from past or present students?

Where do you see this course going in the future
(How do you see it changing and not changing)?

Is there anything else you would like to add about a topic or topics that I have not asked about?

APPENDIX B: STUDENT INTERVIEW QUESTIONS

Note: In no interview were all the questions listed here asked of participants; rather, these questions served as a general guide and reference point during each interview.

Opening Questions

- Tell me briefly about your own academic background.
  - Briefly describe process by which you selected CSM.
  - How chose major--MN Engin.?
  - Where going next?
  - Could you tell me about the kinds of writing you have done in the last few years? (for school, internships, jobs, anything)

- Could you tell me about your experiences with SD?
  - What do you know now as a result of SD that you didn't know in August?
  - What role does writing play in SD?
  - What do you know now about writing as a result of SD that you didn't know in August?
  - Describe the types of writing you did in SD.
  - How is the role writing plays in SD similar to and different from the role it plays in other MN Engin. Courses?
  - How would you describe SD's main advantages or strengths?
  - How would you describe SD's main disadvantages or weaknesses?

- Now I'm going to ask you to conjecture. Given the types of writing you've done in college, which ones will most closely resemble types of writing in the workplace?

Socialization

The term social capital has been used to describe the ability to establish and maintain the relationships that allow people—whether in an organization, culture, or a nation—to achieve common and important goals. Could you tell me how you think professionals in MN Eng. use their social capital—that is, how they establish and maintain key relationships.

  - What role do you think writing plays in establishing and maintaining relationships?

- Could you describe the process in which one goes from being a newcomer in a field to being a fully accepted member of a field? How do newcomers shed their newcomer status?
- How does one know who is an already accepted member of a field like MN Engineering and who is not yet a fully accepted member?
- In your view, what role does writing play in becoming an accepted member of MN Engineering?

Knowledge Conceptions

- Could you tell me as much as possible about how information about new knowledge in a field like MN Engin. circulates? And evolves?
- What is the role of writing in the process of communicating new knowledge? In the process of ensuring that new knowledge continues to evolve?

The Value of Writing in the Field

- Would you say that MN Engin.s generally value writing? In what ways to they communicate this value or lack thereof?
- What might be some of the reasons for this value and/or lack of value?
- What practical purposes does writing serve for a MN engineer?
- What role does writing play in intellectual growth?
  - What role has writing played in terms of intellectual growth in SD?
- Could you tell me whether the act of writing has helped you better learn some technical content?
- Could you describe how you have learned what constitutes effective writing in your field?
  - How do you know effective from ineffective writing? (Criteria you use)
  - How do you know when you've produced effective vs. ineffective writing?

Rhetoric: Especially Persuasion and Audience

- Tell me about the sample piece of writing you brought.
  - What is the intended audience?
  - Purpose? Is it persuasive?
- Tell me about your intended audience for your final report in SD.
  - Purpose?
- Tell me about what you perceive to be the role of persuasion in MN Engineering writing generally?

Writing

- Would most engineers describe themselves as effective writers? Why/why not?
  - Do you think it has something to do with MN Eng. in particular, with Engineering generally, or both or neither?
- I noticed that some of those who were invited to be participants in this study were initially a little reluctant to get involved. Why do you think this might be?
- What does it mean to write like a MN engineer?

PBL

- The type of learning in SD is often described as problem-based learning, which generally involves learning through solving an open-ended problem. What are your thoughts on this type of approach to teaching and learning?
- Is this approach applicable to and realistic preparation for workplace contexts?
- Should engineering educators increase the amount of PBL in the curriculum? Why/why not?

Closing

- Tell me about your overall evaluation of SD as a learning experience.
- Tell me about your overall evaluation of the writing component of SD.
- Conjecture again. Let's imagine it's 2006, and you've been working for three years, and I ask for your assessment of SD. What do you think you would say?
- How useful do you think you'd rank SD compared to other MN Engin. courses?

APPENDIX C: CLIENT INTERVIEW QUESTIONS

Note: In no interview were all the questions listed here asked of participants; rather, these questions served as a general guide and reference point during each interview.

Background questions

- Could you tell me about your professional background
- How many times have you served as a client for SD students?
- Would you describe yourself as a mining engineer?
- Could you tell me more about what your company does?

I. Writing and *Cognitive Growth*

   a. In what ways does the act of writing, of putting ideas into words, facilitate or foster intellectual growth? [III.b.iii furthers this theme]
   b. What purposes does the act of writing serve for a practicing engineer?
   c. In your own work, have you ever had occasions in which the act of writing something helped you better understand some technical content?

II. Role of Writing and *Socialization*

   a. How are newcomers socialized into the profession so they become fully accepted members of their professional workplaces?
   b. How were you socialized into the profession?
   c. What role might writing play in this socialization process?
   d. Do you think SD helps socialize students into their profession? How? Does the writing they do in SD—progress reports and a final report—help in this process of socialization? How/how not?
   e. Some have claimed that to be an effective writer in a particular context, you need to consciously or unconsciously internalize the expectations of your audience, and these expectations implicitly tell you what is important to those readers. What's your response to this idea?
   f. In the last question, I mentioned the idea of what is important to readers, what they value. What would you describe as the core values in mining engineering; in other words, what's important to mining engineers?
   g. How do young mining engineers entering the profession learn those values?

III. *Workplace Writing*

   a. In general, what role does writing play in the workplace?
      i. On average, what percentage of your day do you spend writing?
      ii. What types of documents do you typically write? Length? Purposes? All technical or some non-technical?

iii. Sometimes people say they know good writing when they read it. Could you tell me about what characteristics distinguish more effective from less effective workplace writing?
iv. Does most writing you read meet the criteria you just described (for effective workplace writing)?
v. What role does audience play in written workplace documents? For example, are the documents written to a generalist or non-expert audience different from those written to a highly informed audience? How important is it to understand the full range of audience expectations? What are possible consequences if one does not, perhaps speaking from experience?
vi. What role does persuasion play in written workplace documents? Thinking about documents you've written in the last few months, what role did persuasion play—or not play—in any of those? What features of written documents most effectively persuade mining engineering readers? Are those the same ways as all other engineers or are some unique to the needs of mining engineers?

b. In what ways is writing important for a (mining) engineer?
    i. In what ways do you see value or lack of value placed on writing in professional contexts?
    ii. How would you say writing is regarded by the majority of engineers? Why? In addition to [initial reasons for valuation], what other reasons might explain a low or high value placed on writing?
    iii. Do most engineers find writing difficult? Why/why not?
    iv. What role would you say writing plays in promotion and career advancement? If you had to rate writing ability as a factor in promotion from 1-10, with 10 being absolutely essential and 1 being nonessential, what score would you give? Explain. Any personal experiences—did writing ever help you get promoted?
    v. The term "social capital" refers to the ability to establish and maintain relationships. If any, what role does writing play in establishing and maintaining professional relationships in your sector?
    vi. I'm struggling to understand how engineers value and don't value writing, and I'd like to run by you a working hypothesis to see if I'm on track and to see what factors I need to consider. Response to four-layers theory….
        1. I'm interested in the relationship between the visual and the verbal in workplace writing. For example, some engineers say that when they write, they are thinking in pictures not words, so writing involves a translation of sorts. What's your response to that? Could you help me understand the visual and verbal aspects of your own writing processes? Do you think the writing process you described extends to most engineers?
        2. If a young engineer whom you had hired told you during his or her first month on the job that he didn't think writing mattered to his career success, what would your response be?

c. Is the type of writing students are doing in SD—namely progress reports and a final report with supporting appendices—reflective of and good preparation for workplace writing? Why/why not?
d. What are the most important things you've learned about writing since you began your professional career? How did you learn those things?

Closing questions—

- The type of learning in SD is often called problem-based learning (PBL) because it involves open-ended, realistic or real industrial problems students have to solve. As educators who want to prepare students so they will be successful in their careers, should we be doing more PBL in our curricula? Why or why not?
- Did you have PBL courses in your own academic training? If so, describe.
- What could we improve or change to better prepare engineers for the realities of workplace writing?
- As a client, were you satisfied with the level of performance of the students with whom you have worked? What were their professional strengths and weaknesses?
- Are there any issues you would like address that we did not address?

APPENDIX D: ALUMNI INTERVIEW QUESTIONS

Note: In no interview were all the questions listed here asked of participants; rather, these questions served as a general guide and reference point during each interview.

How would you assess the utility of SD compared to other mining engineering courses? Do you think it was reflective of or useful preparation for the workplace? For workplace writing?

I'm going to ask you to try to conjecture. If you could travel back in time three years, and I was to ask you during your last month of college to assess the utility of SD compared to other mining engineering courses, what might you have said then from that vantage point? Would you have seen the course as useful preparation for the workplace? For workplace writing?

The response you would have given three years ago is (probably) different than the one you gave today. Could you tell me about what factors might account for the change over time?

Same question from the client interviews on knowledge culture's values. What is important for mining engineers? And what factors account for that? What shapes/gives rise to these values?

a. Some have claimed that to be an effective writer in a particular context, you need to consciously or unconsciously internalize the expectations of your audience, and these expectations implicitly tell you what is important to those readers. What's your response to this idea?
b. In the last question, I mentioned the idea of what is important to readers, what they value. What would you describe as the core values in mining engineering; in other words, what's important to mining engineers?

Conceptions of workplace writing (many of the same questions as in the client interviews).

Does a person write typical workplace documents differently when they first start at a job than they do after gaining a few years of experience? How? What factors might account for any shift?