ATTENDING LIKE AN ENGINEER: RHETORIC, DESIGN, AND PROFESSIONALIZATION

by

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Attending Like an Engineer: Rhetoric, Design, and Professionalization

Abstract

By

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“Attending like an Engineer: Rhetoric, Design and Professionalization,” is an ethnography of an engineering design course and a group of engineering students. This IRB-approved study consists of observations of the design course, 9 hours of audiotaped interviews with students and their professor, and 21 hours of videotaped student group work. The class I observed introduced students to the design process and rendered many of the constraints professional engineers work under as part of that process. By analyzing the data in light of rhetorical theory and theories of embodied cognition, I argue that the process of professionalizing student engineers into professional engineers is a practice of directing and training the students’ attention through learning design and learning to write. At base, the class has students engage in design work not to produce a product or a process, but to cultivate and display attention to the ways professional engineering work is carried out. Students come to attend to engineering problems not as textbook problems, but as problems that are thoroughly intertwined with real-world constraints. Students take up and contest the professional attention they taught and bring it to bear on how they frame design problems; how they make judgments in the design process; and how they compose the genres of professional engineering.
My study offers three important findings for technical communication, engineering education, and writing in the disciplines: 1) genre work introduces students to the economy of a profession’s activities by composing texts that mediate and filter design efforts; 2) learning through design is a dynamic rather than transmissive process, where received disciplinary knowledge is contested and negotiated in the emergent embodied and social order of teamwork; 3) and a focus on how students are taught to attend closes the gap between learning to write like a professional and learning to think like a professional. Attending means selecting, structuring, and displaying disciplinary knowledge, forming a profession’s practice and domain of scrutiny.
Chapter 1: Introduction

The topic of my dissertation is how engineering students enact the engineering design process for their first time. I situate my dissertation within the field of professional and technical communication (TPC) and specifically, its focus on professionalization and the transition from school to work writing. Research on how to prepare students for workplace writing and the challenges students face in making such a transition is extensive: however two major concerns consistently appear. The first major issue is the difference between school and work learning environments. Learning in school is guided by the instructor, is student-focused and is the actual motive behind the entire enterprise, while learning at work is informal, incidental, product- and monetarily focused, and emphatically not the motive the of the enterprise (Freedman & Adam, 1996). Thus, there is a gap in learning skills created by the difference between school and work environments and therefore, there are challenges for students that need to take on professional roles that school instruction cannot fully create or prepare them for.

Another issue facing the students going into work environments as well as the teachers trying to prepare them for the transition is the motive behind the writing itself. At work, writing is transactional, solely communicating its purpose and not officially evaluated for any other criteria; writing in school is pseudo-transactional and is evaluated for competence by a teacher, and much less for the purpose it communicates (Petraglia, 1995; Spinuzzi, 2004; Winsor, 1996). Writing in school can mirror the genre, exigency, and content of workplace writing, but the participants in the rhetorical situation of the university remain student and teacher, and not employer and employee.
There are several ways to more finely delineate and deal with these two broad issues within TPC. The most prevalent and influential approaches are found within Rhetorical Genre Studies (RGS), which generally focus on the textual genres students need to learn, how they learn them, and how genre knowledge figures students and new workers into professional practice (see Artemeva, 2004 for an overview). RGS goes beyond identifying genres with certain formal features of texts and sees them as symbolic actions that constitute typical social and professional situations, (Artemeva, 2003; Miller, 1994a). RGS also understands students’ acquisition of genre knowledge as the fundamental element in learning to write for the professions (Russell, 2007). Genres are considered tools for discursive agency (Russell, 1997; Winsor, 2003), as a form of situated cognition (Berkenkotter & Huckin, 1995), as shaping identity (Artemeva, 2005) and subjectivity (Emmons, 2009) as well as textual links in greater chains of work activity (Ding, 2008; Russell, 1997).

At base, genres form communities, in that they allow specific kinds of communications in certain forms to circulate among people in typical, but heterogeneous situations, thus tying together individuals and groups who may be separated in time, place, and task. Genres not only form communities, but they are the engines of change within communities. According to Russell (1997), communities and power within those communities are stabilized by systems of genres, and to effect change and accumulate power, people must first appropriate genres to gain a voice in decision-making (p.538). Genre, then, is not simply an academic concept and skill students should learn; it is an ability that needs to be developed so that students can become fully participating community members.
The analysis of genre knowledge and work has been coupled with and extended by socio-cognitive approaches to learning and activity (e.g. Beaufort, 2000; Winsor, 2001). These approaches have shown genre’s centrality to communicative action; how agents come to be accepted as productive colleagues in workplaces through genre writing that becomes company knowledge and action; and how factors such as timing and hierarchy can affect the reception of knowledge. This work demonstrates the centrality of genre in learning to write in and for professional settings and forms the background of my research into how engineering students understand and learn to produce writing in the design process. The design process is a genre set that circulates in the larger genre system of engineering work. Students with knowledge of the design process are provided with the communicative tools to begin to participate in their profession.

While this research gets to the heart of how texts function in school and the workplace and how students view their composition and rhetorical power, other studies examine student performances, both textual and oral, as experiments with their eventual professional roles. Studies in the attempt to professionalize students, such as Dannels’ (2000) follow instructors’ attempts to provide students with an awareness of the professional constraints of the workplace, and how these attempts are undercut by the situated nature of the academic classroom. The two realms, school and the workplace, are kept separate not so much by the genres themselves, but by the situated nature of the writing that takes place within them, which is always answerable to the immediate goals of the context, either school or work. Attempts to ameliorate this difference have focused on providing students with experiences and skills that will have them prepared for the
complex roles they will assume in the workplace. Brady and Schreiber (2013) describe how teaching students to take inventories of the skills they possess and the many roles they undertake in arising situations prepare them to meet the rigors of skill-assessments in the workplace. Engineering cooperatives (Parsons, Caylor, & Simmons, 2005), client-based projects (Breuch, 2001; Wojahn et al., 2001) and ethnographies examining the writing responsibilities of new employees (Beaufort, 2000) offer different perspectives on the kinds of roles students will take as professionals and the kind of skills they will need to fulfill those roles.

I conducted an ethnography where I observed and took field notes of an engineering design class, video recorded student design work, and interviewed engineering students and their professor. I came to see the activity in the classroom and between design team members as the work of learning to attend in a certain way to particular objects and tasks of engineering. Genres, while crucial, became spaces of instruction and contestation rather than simply mediation. In the class lectures, the professor would point out different ways of conceiving of design work, different ways of thinking about engineering, and tell students the factors they had to be mindful of as they went through the design process. The professor selected for students what was important to attend to in design work, and through her demonstrations, the strategies she imparted for designing, and the procedures inculcated by professional engineering genres, they were taught how to attend to design work. Within the design group, I observed students bringing those concerns from the classroom to bear on their design projects. The piloting of attention however was not as straightforward as that. Within design practice students ordered their activities in ways that emerged from their situated, singular group
dynamics. They brainstormed, argued, and sketched throughout the semester I observed them. In these interactions the students selected what they thought was important from the design class and combined those concerns with their own developing perspectives on design work. From this negotiation of attention, a design was textually instantiated and presented to the professor and class for their critique and grade. The design presentation was a culminating performance of professionalism, one that had its origins in the structuring activities of class lectures, class materials, and design work. However, the focus of this dissertation will not be on the structuring effect of demonstrations, strategies, and genres, but instead on design activity that ignored, complemented, or contested the sanctioned attentional structures of the classroom. Through this focus, the data reveals the stakes of distance and context for educating attention and procedure in the classroom.

Attention is a heuristic concept in this dissertation, serving to orient the analysis to the dynamics of moments that can tell us something of what learning and performing engineering design involves. I offer an illustration of what I mean when I use the term attention. Learning this design process involves, what Gibson (1960) and others (E. Gibson, 1963; Ingold, 2002) have termed, an “education of attention” (p.139), a process whereby students (or any newcomers to a community) learn how to properly attend to the objects of their discipline. This education involves both learning what objects to attend to and how to attend to them. In order to develop this awareness in the field of engineering, students are shown and asked to compose both written and oral texts, visual aids, and designs. Specifically, students are taught what to select from many sources of data, how to emphasize these selected data in their decision making, and are critiqued and evaluated
on how well they perform their educated attention through text production (see Lymer, 2009). For instance, the teacher of an engineering design course I will examine introduced her students to patents, by explaining the format and functions of patents and where to find them. The professor who I call by the pseudonym Dr. Connolly, however, was not interested so much in describing patent literature to students; rather she emphasized how to read them for specific purposes within engineering design. She directed the students’ attention to certain sections of the patent, for instance, the claims section where the patent holder outlines why this particular process or product is different from others before it, and therefore deserves to be legally protected. Students looking to find out if their own design infringes on others can skip all of the other sections of the patent and head straight to the pertinent information.

The actions of the professor were displayed on an overhead projector. What is projected for the students are the professor’s hands, the pencil she holds, and the patent upon which she focuses her attention. Her scrolling through the patent’s sections on the projector, deictically gesturing to parts of the text she verbally expands upon, selects for students the sections that will have to attend to for both the upcoming homework assignment and for general engineering practice. The professor’s actions are similar to Goodwin’s (1994) accounts of highlighting, “making specific phenomena in a complex perceptual salient by marking them” (Goodwin, 1994, p.606). Goodwin performs a microanalysis of the discursive actions of an archaeological dig and the defense of the police accused of assaulting of Rodney King to show professionals taking an element from a field of undifferentiated phenomena and differentiating it by marking it or pointing it out for viewers. Professor Connolly’s actions differ from the actions of
Goodwin’s archaeology professor and defense team, however, in that she was not only marking salient phenomena to be seen in a particular way, but demonstrating a particular way of seeing, or in the terms I am working with here, she demonstrated a particular way to attend to patents, scanning them like an engineer would. She did so by circumscribing the patent with her pencil and indexical talk. She elaborated the professional use of patents, by noting that in her experience, the engineers she had worked with in the past would simply go right to the Claims section since therein was the most pertinent information. This small moment of demonstration exhibits an important document for engineering work (the patent), a professional skill of ‘reading’ a patent for engineering, and an appeal to the authority of working engineers to reinforce the demonstration as part of the practice of the community students must enter.

Dr. Connolly taught the students to scan the patent for the relevant information they will take up as a starting point for their own product ideas, showing them where they need to look in order to “design around” existing products and processes. Students then conduct their own research on patents for a homework assignment; they find patents, scan them in the way they were taught, and attend to those features of the patent that will provide information for (say) brainstorming and idea generation. Eventually, the students will summarize their findings in writing to show the professor they have learned to perform the relevant attentional abilities.

This seemingly simple act of instruction highlights how attention works in the engineering design classroom. Students are taught how and what to select through an act of demonstration that emphasizes relevant elements for the performance of a task. This what I call attention from an adverbial perspective as opposed to attention as a process
that highlights the internal, cognitive and neural mechanisms processing stimuli and
directing interaction. Scanning a patent is one among many instances in which students’
attention is tuned gradually to the way professional engineering design work is carried
out. Dr. Connolly’s lectures are one vehicle for demonstrations for how to read, view, or
understand the objects involved in engineering design, but students will also learn to take
up these attentional practices through strategies for designing, genre work, and through
practical engagement with their small group projects. The professor’s lectures and course
materials structures when, how, and to what end students practice their new attentional
abilities, but the cultivation of these abilities is in contention with the dynamics of the
student groups themselves, which I designate as a problem of attunement. In other words,
the structuring attention of the classroom does not always order the activity of the design
group.

In later sections, I will return to the patent example to elaborate the idea of
attention with research from cognitive linguistics, embodied cognition, philosophy of
psychology, rhetorical theory, and Rhetorical Genre Studies (RGS). Before that
discussion, I will provide a problem statement and project description. But I want to
forecast descriptions of key terms. Rhetoric has two main components in the dissertation:
the first emphasizes the educational practices to form a competent practitioner of an art,
and the second is of symbolic and bodily inducements to action and collaboration. The
first definition is dominant in this, the second chapter and the last two chapters, while
rhetoric as a symbolic and embodied inducement is used in the chapters on framing and
judgment (though rhetoric as education is powered and facilitated by rhetoric as
inducement). Design is major concept that will go through permutations, but to begin, I
borrow ABET’s definition of engineering design as “Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic science and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective” (ABET, 2014). This basic definition of design will become expanded as design theory is discussed below. Finally, I designate professionalization as the introduction of and practice in work under professional demands, constraints, and values. Professionalization in engineering means understanding and attending to ways to design components that find a balance between competing constraints.

**Learning Engineering Design:**

My dissertation first argues that the process of professionalizing a student engineer into a professional engineer is a process of directing and training the students’ attention. My argument stems from an interpretation of ethnographic data gathered from an engineering design class at an urban university on the north shore of the United States over the course of a semester of 16 weeks. The engineering design class introduces students to the engineering design process and simulates many of the constraints under which professional engineers work. Professional engineering and design was presented to the class by the teacher and the class materials, and students were to work those sources of presentation into their design activity in order to create their own presentations that exhibited, performed, and demonstrated their developing professional attention. At base, the engineering design class had students engage in design work not to produce a product or a process, but to cultivate and display attention to the way professional engineering is carried out.
In the bulk of the dissertation, I students practicing design in ways demonstrating the difficulty of transmitting the attentional structures of the classroom to group. As an ethnography into the education and practice of engineering and technology, the project builds on similar studies observing the teaching and practice of science, technology and medicine in technical and professional communication (TPC) (Fountain, 2014; Graves, 2004); engineering education (Downey & Lucenda, 2003; Johri, Olds, & O’Connor, 2014; Stevens., O’Connor., Garrison, Jocuns, & Amos, 2008), design studies (Bucciarelli, 1988, 1994; Fleming, 1998) and science and technology studies (STS) (Alač & Hutchins, 2004; Mody & Kaiser, 2008; Myers, 2008, 2014; Prentice, 2013; Warwick & Kaiser, 2005). Though these studies differ in particular investigative interests, they have in common an emphasis on the social and mediated ways students and practitioners do STEM work. This investigation looks at a pivotal point in an engineer’s education, when the ‘accountable disciplinary knowledge” (Stevens, O’Connor, Garrison, Jocuns, & Amos, 2008) goes from a decontextualized textbook problem to a contextualized design problem (Bucciarelli, 1994). In the engineering class, design problems were undertaken in groups and design solutions were proposed in a social process whereby ambiguous and uncertain design ideas are negotiated textually (Roth, 2014), discursively (Bucciarelli, 1988) and through the body. (Alač & Hutchins, 2004; Fountain, 2014; Myers, 2008; Prentice, 2013). Significantly, learning the design process involved learning the values of professional engineering, and those values were instilled in students through an array of rhetorical strategies embodied in instruction and texts (Fountain, 2014; Myers, 2014). My dissertation, then, is an ethnographic investigation that describes how students are rhetorically taught to attend to engineering in a new way.
I hope to offer a deeper understanding of how students become professionalized and how they engage in professionalizing activities. I hope to persuade the reader of the importance and versatility of a concept of attention in relation to pedagogy, visualization practices, design, rhetoric, and embodiment. By focusing on what students actually do to produce work for a class simulating professional engineering practice, I intend to provide material to help teachers and researchers reflect on how students learn to attend like professionals and how we can better foster their attentional abilities.

In the remainder of the introduction, I first outline the trajectory of the project, describing the themes and sequence of the dissertation, and the research literature from which it is situated. The focus then turns to defining and describing just what I mean by the two most important keywords in the dissertation, attention and rhetoric. Following the outline and explanation of key concepts, I will state the argument and propose three research questions that guide the dissertation.

I then provide a description of the observational methods and analytical strategies. Finally, I offer synopses of the dissertation’s contents: an in-depth chapter on the field site and further look into how attention work in the classroom and the with group activity; a chapter on the framing activity of design; a chapter on the deployment of ‘engineering judgment’ in design work; and a chapter on the genre of the design presentation. My conclusion elaborates on the consequences my dissertation has for TPC principally, but also for engineering education, design studies, and rhetoric of technology, as well.

The Dissertation in Outline and Literature Review:
Professionalism has been a concern for engineering ever since the discipline’s inception (Henderson, 1991b, 1999; Wilensky, 1964). Many education and industry organizations have made efforts to systematize and regulate bodies of knowledge and technical skills to professionalize engineering work to maintain consistent standards of work. One of the most consequential efforts was ABET Inc.’s 2000 publication of guidelines colleges and universities must meet in order to have their programs accredited. The guidelines are a list of outcomes that engineering and technical and professional communication teachers must ensure students meet. In meeting these guidelines, educators have implemented numerous kinds of service learning, project based learning and interdisciplinary design courses to develop the skills that will serve student engineers in their professional futures. The necessity and the effectiveness of these pedagogical approaches for meeting the demands of professionalism have been thoroughly evaluated, assessed, and elaborated in the research literature (Dutson, Todd, Magleby, & Sorensen, 1997; Fedler & Brent, 2003; Froyd, Wankat, & Smith, 2012; Parsons, Caylor, & Simmons, 2005; Reave, 2004; Shuman, Besterfield-Sacre, & McGourty. 2005; Williams, 2001). What goes under examined is how student engineers start to become professionalized within these courses (though see Craig, Lerner, & Poe 2008, 2012; Stevens, O’Connor, Garrison, Jocuns, & Amos. 2008). Questions such as “How do students become professionalized? By what means? To what extent are they professionalized and to what extent can they be professionalized?” are less often asked than questions like “Are they being professionalized sufficiently? Why or why not?”

While both types of questions are important, the one that interests me and the one I believe TPC has excelled in asking is, “How do students become professionalized?”
TPC literature immediately answers that by writing professional and disciplinary genres and through seeing objects of professional scrutiny in a professional way (Bazerman, 2009; Russel & Harms 2010; Beaufort, 2000; Dannels, 2000; Fountain, 2014; Freedman, Adam, & Smart, 1994; Leydens, 2008; Prior, 1994; Winsor, 1996, 2001). These two activities, in fact, reinforce and mutually elaborate each other, as writing becomes of way seeing and thinking professionally, while objects in their situatedness become objects of a “professional vision,” facilitating symbolic actions with people in and outside of a professional community (Goodwin, 1994). How do students get to that point, though, where they can see objects in a professional way and where they can write and communicate in a way that is intelligible and effective? My answer is their attention is piloted so particular objects, concerns, and processes of interaction begin to coalesce into a sanctioned practice.

Attention is a dispositional “whole-organism state” (Allport, 2011, p. 50) whereby an agent directs activity to an object in the pursuance of a task (Csordas 1992; Mole, 2010). The teacher in order to chart a course for student action, directs this disposition and gives it professional form through instruction and texts regulating its performance and display. Attention is performed and maintained through many strategies and tactics. Attention is fragile but responsive, requiring careful coordination and navigation. I argue that an education of attention (E. Gibson, 1963; J. Gibson, 1960; Ingold, 2002) is the foremost goal of the engineering design classroom. Education not only fixes and trains attention, it also provides a way to instill in students the appropriate motives for undertaking tasks. An education of attention is not only cognitive or bodily; it is moral, as well.
Through attending to professional objects and practices, students learn to account for professional concerns in a professional way. This process is topicalized in the engineering design classroom where students often find themselves encountering engineering problems as actual engineering problems for the first time. Prior to entering an engineering design class, engineering problems were mathematics and science problems (Bucciarelli, 1994). They were encountered in the form of test questions and textbook problems, though perhaps students had experience with engineering a robot for a high school competition or they participated in Design For America, for many students the engineering design class is the introduction to engineering as it is conceptualized and to a small degree practiced by industry (Dym, Agogino, Eris, Frey & Leifer, 2005; Friesen, Taylor & Britton, 2005; Troy, Keller, Kiper, & Kerr, 2008). The engineering design class simulates the professional constraints engineers face in professional practice, and students are expected to account for these constraints by attending to topics of usability, feasibility, marketability, durability, manufacturability and sustainability through their designs. Students are also expected to research a customer demographic, the context for the design’s utilization, and make design decisions balancing efficiency versus cost. The actual design emerges through the attentive negotiation and navigation of this activity.

The engineering design classroom is a place where professional practice is rhetorically inculcated and developed. Students are induced to perform certain kinds of action in professionally appropriate ways. The lectures, textbooks, and other materials teach a professional attention to the ways and ends engineering design work is accomplished. Each educational activity and object directs and attunes the student’s
attention, having her keep in mind certain constraints, concerns, procedures, and resources that form competent design practice. This directing of attention populates a kind of field that situates students’ design work. However, as I will contend throughout this dissertation, this field is not a cognitive frame that is built through instruction, transported intact, and utilized in design work. Nor should the direction of attention be thought of as one-way transmission of certain types of behavior or as a conduit for professional practice. Rather an attentional field and the actions of students that evince and perform it are enacted and negotiated through design work itself.

Design work is the activity of understanding and proposing solutions to problems in indeterminate and contingent circumstances (Buchanan, 1992; Bucciarelli, 1994; Coyne, 2005; Dorst, 2006; Horst, 1982). In the engineering design classroom, however, design work is better structured as students are given assigned projects that delineate the stakeholders and context of the design situation. The prompt is vague enough, however, to ensure students engage in their own problem-setting to a significant degree. The freedom to problem-set is one example of the unique features of the design classroom. In order to manage the direction of fit between general principles and situated and indeterminate circumstances, students are constantly framing and reframing their design efforts. Through talk at group meetings, in sketching out ideas, gesticulating in imitation of mechanical motions, and searching the Internet, students draw each other’s attention to various concerns and considerations for creating a design. In design studies, framing is often understood as the impact of designers’ assumptions, desires, and values on the design (Hey, Joyce, & Beckman, 2007; Paton & Dorst, 2011; Schön, 1983, 1984; Stumpf & McDonnel, 2001; Valkenburg & Dorst, 1998). Framing is manifested in actions made
by designers to order their activity in particular way. Through the course of designing, however, frames are shown to be fragile as students struggle to maintain them throughout the design process as new considerations are constantly introduced and negotiated. Within this activity the attention they are taught in the classroom is brought to bear on the design project as components of frames. Ultimately, even professionally sanctioned attention is subject to the same process of framing and reframing as students develop their design.

While going through the design process and framing the work they do, students learn to make engineering and design judgments about their project (Holt, 1997; Kortzman and Boling, 2014; Nelson and Stolterman, 2003). Judgment is endemic to the design process, as opportunities to decide on courses of action, weigh options, and negotiate between opinions occurs throughout designing. Judgments are creative decisions to act with the knowledge of the constraints of a given situation developed through experience (Davis, 2012). In an undergraduate design project, students do not have the requisite engineering experience to exercise sound judgment on design issues. Instead, they resort to their everyday experience and use common reasoning to supplement the difficult mathematics and mechanics they have not yet mastered. How judgments are made and the form they take provide evidence for how students attend to emerging issues.

Unlike professional engineers, students’ designs usually do not become actual products for consumers, they become presentations to the teacher and the class. Therefore, students’ attention and judgment are keyed towards and determined by the reality of the classroom context. Students must navigate the tortuous complexity of
composing professional genres as both facsimiles of professional work and actual school work (Artemeva, Logie, and St. Martin, 1999; Dannels, 2010; Freedman and Adam 1996; Russell, 1997). The texts and oral presentations students make provides the teacher with a performance of the professional attention they have constructed throughout the class. Students demonstrate and display their attention to the details the teacher and her instructional materials made salient throughout the semester. They show textually and verbally how they account for constraints, meet deadlines, and work as a team. A consequence of meeting the genre demands of the professions is the filtering out of different ways of conceiving of engineering work. In other words, as students design with and in accordance with the attention the engineering design course has promoted, they must necessarily bracket or discard other ways of thinking about engineering and design. Learning to be a professional not only means attending to engineering problems like a professional engineer; it also means learning the sanctioned ways engineering work is displayed and valued.

The above outline of the course and the dissertation project briefly touches on my focus in the following pages. In the rest of the introduction I give a more detailed explanation of what I mean by attention and rhetoric, and why I use those terms. I will then describe the argument of the dissertation: namely, that becoming a professional engineer starts with learning to attend like a professional engineer. Learning to attend is not only a process of transmission, rather it is constructed rhetorically through different kinds of performances responsive to situational constraints. Following the explanation of key terms and argument will be a description of the field sites and methods of the study. Finally, I will provide a brief description of the contents of the dissertation chapters.
Attention and Rhetoric in the Engineering Design Classroom:

Attention is shared, contested, refined, imitated, and materialized, extended, and contested through the production of texts. The exploration of this process through a focus on attention has not been discussed in technical and professional communication (TPC) and engineering education. Though there are many studies on how novices and students learn to write (Beaufort 2000; Ding, 2008; Tardy, 2009), learn to see and use objects of work from a professional perspective (Lymer, 2009; Winsor, 2001), and how to perform professional skills (Dannels, 2000; Freedman, Adam, & Smart, 1994), the process whereby students learn to attend to what their future profession deems important is less discussed, or not recently discussed (see Prior, 1994; Berkenkotter & Huckin, 1995).

A focus on attention affords TPC, engineering education and related fields a way of closely examining how students take up what is taught to them. Todd Oakley (2009) notes that in the learning process, first we attend, then we perceive what we attend, remember what we perceive, and learn what we remember (Oakley, 2009, p.25). However, it is more phenomenologically consistent to say attention allows for new things to be noticed by perception, new regions of the phenomenal world to be constructed (Csordas, 1993; Merleau-Ponty, 2002, p.35). An education of attention is a process of learning how to construct perception and the object of perception through/in practice. Many studies examine people learning how to see and perceive professionally and academically (Alač & Hutchins, 2004; Aruigemma, Chandrasekhar, Nersessian, & Newstetter, 2013; Coopmans, Vertesi, Lynch, and Woolgar, 2014; Fountain, 2014; Goodwin, 1994; Lymer, 2009; Phillabaum, 2005; Styhre, 2010) but few are the studies that examine how we are taught to attend professionally and academically. The reasons
for this absence are not clear to me. Possibly because the acts of seeing and perceiving are considered to cover enough ground of how we come to be knowledgeable, socialized, and professionalized that a study of only attention is tough to carve out.

The healthy interest in attention from psychology and cognitive science (Mole, Smithies, & Wu 2011; Oakley, 2009), plus the renewed interest in attention from philosophy (Mole, 2011; Watzl, 2011a, 2011b) belies that assumption. Research across disciplines point to attention’s potential to enrich understanding of how activities are ordered and conducted. When faced with such a plenitude of approaches, the difficulty then becomes how to understand attention. Observing engineering students doing design work and in the classroom with their teacher, it became clear that attention was vital to what was learned and expressed. The kind of attention that was facilitating learning in the classroom seemed remote from those approaches that viewed attention as a fundamentally cognitive process, and instead closer to a more embodied, ‘adverbial’ approach that highlights the physical actions and textual practices that maintain focus on and towards objects.

Allow me to reintroduce the patent example to foreground an adverbial view of attention using Oakley’s (2009) Greater Attention system. Oakley’s system is helpful in providing a lens to understand the incremental movements of establishing and directing attention. Dr. Connolly first orients the students’ attentional resources to the patent as a projection on the screen behind her by introducing the topic. She establishes joint attention\(^1\) by capturing in the lecture the student’s eye contact and thence, their

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\(^1\) Joint attention is a research area for cognitive science (Tomasello, 1995), psychology (Bruner, 1995), psycholinguistics (Clark, 1996), and philosophy of mind (Elian, 2005). Minimally, joint attention describes the attention of two or more agents on one object and the awareness that both parties are attending to
compliance. Students are disposed to orient to the teacher’s activity, and can easily detect the manner in which to behave towards it, because the activity is framed by the lecture situation in which they find themselves. The two parties, professor and students, sustain and control their attention by devoting all of their attentional resources to the activity at hand; that is, students continue to look on quietly and forego searching the internet, and Dr. Connolly directs her actions to expounding the topic, guiding students’ gaze through the patent information. She oscillates their attention from scanning the patent, to commenting on how professional engineers scan (see Oakley, 2009, chapter 2 for a discussion of his system). Her movements, display, and talk are pedagogical and as such, direct the students’ attention to 1) an important document for engineers; 2) a way to skim or read that document; and 3) advice on how to use the document for future ends, essentially showing how the text can become a tool for concept generation. Attention here is a choreography of intentional display, movement, and talk to select an object within the frame of a task and direct particular actions for performance.

The patent example can be described in two ways, as a process and as a manner of being towards an object within a task. Oakley’s (2009) greater attention system incorporates both viewpoints, but he does not distinguish between the two. I pull the characterization of these two views of attention, one as a process, the other adverbial from Mole (2010). Mole gives a brief history of the concept of attention, from the rise of psychology in the early to mid-19th century to the present day. He distinguishes between the dominant process view of attention associated with William James and the less popular adverbial view that was forcefully argued by F.H. Bradley, echoed to an extent
by behaviorists in the first half of the 20th century, and taken up by ordinary language philosophers such as Gilbert Ryle and Allan White. The process view identifies attention with cognitive processes. That is, attention is understood as a selection system, a processing constraint, or a type of control process substantiated in neurophysiological processes (Allport, 2011). The adverbial view identifies attention not with any specific cognitive mechanisms, or any particular process at all, but instead as the manner in which someone undertakes a task (Mole, 2010, Chapter 4). Mole suggests that the process view is more suitable to discuss phenomena like combustion and digestion, whereas attention is better understood as a concept similar to haste or style and therefore demands an explanation about the manner in which something is done or undertaken. The process view looks for processes underlying attention, whereas the adverbial view seeks to know what it means for something to be done attentively.2

To use the patent example again, Dr. Connolly is not only drawing student attention to what she is doing at the lectern; she demonstrates the manner in which professional engineers attend to patents; searching the pertinent information by scanning the sections and using the patent to generate ideas. It is the adverbial view that gives us some purchase on how students learn to attend to engineering problems like professional engineers. Taking this view allows the ways students attend and the ways they are taught to attend to come to the forefront. The adverbial view trains focus on whether student actions are attentive and what those actions achieve rather than on which cognitive processes are at work inside the students’ heads. Needless to say, questions of how

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2 Attention in this dissertation should be understood as attending. I use attention as a matter of habit and in order not to say anything too awkward sounding, but attention is an activity, and should be thought of as attending even when ‘attention’ is used.
students are taught to attend and how they attend in group work still need to be
addressed. What provides some insight into these questions is a rhetorical theory that
specifies the kind of role rhetoric has in a pedagogical space. The engineering design
course does not impart technical knowledge. Rather, students are taught to enact the
design process as a way of attending to engineering problems and then perform that
attention through text production and oral presentations. The course attempts to fashion a
student that can understand and speak to concerns of engineering in a way that is
intelligible and acceptable to a professional community. This kind of training produces a
well-versed engineer and rhetor of engineering.

The connection between rhetoric and attention has received considerable interest
from several rhetorical theorists. Burke (1966), Lanham (2006), and Prelli (2006) make
attention a resource and capability rhetoric tries to capture and direct. Burke’s (1966)
discussion of “terministic screens” is the seminal text of rhetorical theory’s interest in
attention as the object of rhetoric’s pursuit. Burke (1966) understood symbol use as acts
of “directing the attention” of an audience or interlocutor to some particular perspective,
worldview, or object: “nomenclature necessarily directs attention into some channels
rather than others” (p. 45). Burke extended the power of terministic screens by conflating
symbol use with uses of reasoning, and Prelli (1990) further extended Burke’s insights
into a rhetorical conception of Kuhn’s (1970) paradigms of scientific activity, and later
coined the attention directing composition of displays achievements of “rhetorical
by diagnosing the information age as a time where the abundance of information calls for
the management of attentional resources through the rhetorical canon of style. Each of
these three theorists strengthens the relationship between attention and rhetoric by pointing to rhetoric’s fundamental ability to direct attention to reveal and reinforce concepts and aggregate knowledge.

When narrowing the focus to the classroom, the approach to rhetoric that illuminates the professionalizing process of the engineering design class is that which understands rhetoric as the art of producing a speaker. Walker (2011) specifies four common understandings of rhetoric: rhetoric as persuasive discourse; rhetoric as a collection of persuasive devices; rhetoric as a critical hermeneutic; and rhetoric as the teaching of a rhetorical capacity to think, speak, and write. It is the last that Walker decides as the most important and fundamental since it includes the other three definitions and defines a distinct academic enterprise (p. 1-4; see also Graff & Leff, 2005). It is true that the teachers Walker has in mind are those who teach rhetoric and composition, TPC, or communication studies, and not Dr. Connolly who is a material scientist and professor in the Engineering Department. The difference, however, is not so stark. Though not trained in rhetoric herself, the professor’s goal is to develop in students a capacity to undertake a process that is predominantly carried out through verbal and textual means that include invention, decision-making, deliberation, persuasion, judgment and audience analysis in indeterminate and contingent circumstances. Rhetoric as the art of producing competent speakers and writers able to adapt to emergent situation (Leff, 1999) is integral to the course’s purpose. Part of the work of this dissertation is to show where the two orientations, rhetorical theory and engineering education, can elaborate and reinforce each other.
It is nearly axiomatic for TPC that engineering work is substantially rhetorical (Lewis 2000; Miller & Seltzer, 1985; Winsor, 1996), and this point has been recognized in design studies (Buchanan, 1985, 2001, 2009; Fleming, 1997, 1998; Rittel, 1982) and in engineering itself (Ballard & Koskela, 2013). The presentations of design, documentation, and actual design work are all persuasive activities that use rhetorical strategies and tactics to achieve their purposes. They not only direct student’s attention to specific objects and specify the manner in which to act towards those objects, but in their capacity as genres, they direct the motivations (Miller, 1994a) and intentions (Bazerman, 1994) a student can have. Dorothy Winsor’s (1994; 1996; & 1998) work on the rhetorical nature of engineering is especially important here (see Read, 2011 for an overview of Winsor’s work). Winsor shows how writing is central to the work engineers do, how creating textual representations of objects stabilizes them and serve as the basis for hermeneutic practices engineers perform to optimize designs (Winsor, 1998); how writing inventories of decision-making may serves as the basis for further invention (Winsor, 1994); and how novice engineers learn to see their writing and engineering practice as suasory (Winsor, 1996). Other researchers extend and build upon these insights by documenting how discourse, bodies, and texts rhetorically construct the very objects and contexts of engineering and design practice (Haas & Witte, 2001; Geisler & Lewis, 2007; Lloyd & Busby, 2001; Medway, 1996; Medway & Clark, 2003).

It is not simply engineering work that is rhetorical; engineering education, like education in general, is epideictic, a species of rhetoric that inculcates a certain view of a community, legitimates certain work, and praises or blames certain courses of action (Fountain, 2014; Sullivan 1994). The engineering design course, for instance, establishes
the design process as the paradigm for engineering work, praises some formulations of that process over others, and seeks to allow students to practice in the communal art of design. Epideixis not only raises certain beliefs and values over others, but it produces in students a way of attending to the problems the professional community deems worthy of scrutiny. As I will show throughout the dissertation, the engineering design course attempts to fashion a student whose attending, reasoning, and designing starts to approach that of a professional engineer. This effort is epideictic and establishes the rhetorical proofs the student engineers will have to evidence in their designing performances.

My Argument and Research Questions:

Rhetoric and attention, then, work together in engineering education. I therefore argue that the process of forming the engineer rhetor is a directing of attention: how to view, frame, think, construct, judge, write, and perform like professional engineers. Students are taught what to attend to and in some cases how to attend in lectures, through course work, and through the textbook. Students take those concerns into their design work with team members and there the manner of attending from the course is contested and reformulated through practice. The attention structured by the design process is textual and verbally performed in class presentations, a genre that responds to the epideictic features of the course. My study is guided by the following research questions:

1. What is the role of attention in the training of student engineers in a design course?
2. How are students’ attention directed through the texts, techniques, and communicative practices of the course?
3. Do students take up these processes of attention in their collaborative work with the texts, techniques, and communicative practices involved in creating design projects? How do they contest them?

4. What does an investigation of the situated design activities of students tell TPC teachers and researchers about the transmission of attention through texts and the actual design work of students?

More generally, my dissertation seeks to explain how student engineers learning to become professional engineers negotiate and accomplish attending, communicating, and writing.

Field Site:

The primary field site is an undergraduate engineering classroom at Case Western Reserve University in the fall semester of 2014. The class is EMAE 260: Design and Manufacturing I, an engineering course that requires students to design a product in small groups. The class description from the course syllabus reads:

This is the second course of a 3-course sequence focusing on "Engineering Design and Manufacturing." This course develops students' competence and self-confidence as design engineers by exposing the students to design as a creative process and its relationship with modern manufacturing practices. The outcomes of the course focus on the student's [sic] ability to apply their knowledge of mathematics, science, and engineering to design a system, component, or process that meets desired needs within realistic, multi-dimensional constraints, such as: economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. Additionally, students will be given the opportunity to identify, formulate, and solve engineering problems, while applying professional and ethical practices. Professional communication skills are emphasized and expected during all stages of the design process.

EMAE 260 is the second in a three-class sequence that begins with EMAE 160, an introduction to manufacturing methods and CAD software, and ends with EMAE 360, a course that has groups of students work together on one project with minimal teacher
intervention. EMAE 260 takes the new found familiarity with manufacturing methods and CAD software students develop in EMAE 160 and has them apply it to the design process and the simulated constraints of professional practice. The class’s aims, expectations, and outcomes are consistent with other engineering design courses across the world (Atman et al., 2014), and provide the kind of educational environment to best understand the process of engineering professionalization.

EMAE 260 was not only occupied with meeting ABET requirements. Additionally, the class aimed to instill in students a sense of the responsibly professional engineers take on. Responsibilities included ensuring the public safety, health, and welfare (Mitcham, 2009) and balancing business priorities with engineering ethics. These were duties that were forecasted by the professor as things students would have to be prepared to assume responsibility for, and they crept into student projects through Professor Connolly’s insistence on having students think about their designs with these issues in mind. Larger issues of professionalization were gathered into thinking of not only (say) the user’s satisfaction, but her safety and health as well. For Davis (1996), adherence to particular ethical standards is what makes a professional engineer a professional, in addition to particular occupational knowledge. This dissertation focuses on the occupational knowledge, but it acknowledges the centrality of ethics in professional engineering. And I believe the focus on constraints can be widened in further research to accommodate the ethics of constraints.

The classroom itself consisted of four tiers of seats in a semicircle facing a blackboard with a projector and lectern where Professor Connolly presented material. Time in the classroom is spent lecturing and giving presentations three times a week for
fifty minutes. Students are put into groups of around 7-8 early in the semester and told to meet throughout the semester to work on their design projects. Students tend to meet in the library, computer labs, eating areas, and virtually through Google Docs and email. The project of the course is to design a product that answers the specifications provided by the professor, and the design process consists of creating a team charter, appointing team positions, creating a Gantt chart to segment the phases of the design, and using software to create and document the iterations of the design. Each group is assigned to design a product: either a chainless bicycle, a portable water desalinization device, or a solar tracker for a resident of southern Ontario. Each group works outside of class on their assignment and is required to give updates on their group’s progress in oral presentations three times, including for the final project, throughout the semester. At each presentation, students give PowerPoint presentations on their completion of a stage of the design process. They then project their future course of action and explain what remains to be done. These PowerPoints consist of problem statements, decision-making procedures, materials and manufacturing methods for the product, iterations and components of the design, risk assessments, and summaries of team member roles. At the end of each presentation, fellow students and teachers ask questions or critique the plans or designs of their peers, and the presenting students justify their choices and designs. For the class’s final project, students present the professor and their fellow classmates with a finished design, and send the professor electronic files of the texts and documents of the design process. Students were expected to attend a 50 minute lecture three times a week, complete homework and several tests, and meet weekly with their group.

Methods of Data Collection and Analysis:
I combined observational field notes of the entire course with video recordings of students' interactions in their project teams and one-on-one interviews. Overall, the approach to qualitative analysis is heavily informed by Maxwell (2013), who questions the view of qualitative analysis as a linear design starting with goals and ending with validity checks. Rather for Maxwell, the components of the research design are understood as interacting and transforming each other as the study progresses. Furthermore, the particular methodological approach is inspired by ethnomethodology, particularly its focus on observing the methods group members use to order and represent their activities (Alač, 2011; Ball and Smith, 2011; Garfinkel, 1967; Lynch 1993).

Observations and Text Collection:

Data collection methods started with attendance of every class to take field notes. In addition to taking field notes, I collected all of the course materials to which both the instructor and the students had access. I had eleven students agree to grant interviews and seven of the eleven students were the one group who volunteered to let me videotape their group work. My requirements for participation in my study were that they were enrolled in the class and that they volunteered. Additionally, the professor herself volunteered to be interviewed. I received approval from my institution’s review board for the entire study. The interviews were semi-structured and ranged from around one hour to twenty minutes.

I transcribed all of the field notes, interviews, and group work using the NVIVO10 program. For the interviews I transcribed the dialogue word-for-word and

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3 I received approval from my institution’s review board for the entire study.
4 A word on tense: Though it is difficult to maintain, I have tried to be consistent in the use of tense throughout this ethnography. I use the past tense primarily to discuss my own or the volunteers past actions. I use the present tense to make general statements about or from the data, and I use the present tense in chapter 4 to narrate students’ mathematical work.
chunked the dialogue by interview question. I then coded each chunk with a descriptive category that named the content of the text. In transcriptions of the students’ group work, I transcribed the group’s activity according to task or topic of discussion. I also used descriptive coding of the content of the activity, paying attention to not only what was said and what was talked about, but how it was said, whether it was sketched, gestured, displayed on a computer, written on a whiteboard, uploaded on Google Drive, etc. Field notes of the lectures were typed up within a week of the events they recorded and subjected to the same descriptive coding. The method of coding, inspired by Emerson, Fritz, and Shaw (2011) was to build up an inventory of codes and categorize data in such a way that one strip of action could be assigned any number of codes. This method demonstrated to me the complexity of the classroom and design group activity. I constructed descriptive categories that purposefully forestalled the creation of abstract judgments while still making perceptual judgments of the activity informed by my ever growing familiarity with what was happening around me. Descriptive or substantive categories such as “Nixing an idea”; “Learning the tools of engineering;” and “Issues with the class” allowed me to stay close to the action and language of participants as they ordered the class, their design activity, and their reflections on their work while also allowing me to manage a large data set (Maxwell, 2013, p.107-115)

All of the texts, graphics, Power Points, designs, and drafts of the team were also collected as well as the course materials provided by the professor, including the lecture slides, syllabus, supplemental materials, homework assignment sheets, and readings from the course text book, *Engineering Design*, by Dieter and Schmidt, 4th edition (2013). The textual materials were analyzed and connected with their appearance and impact in
the sequence of the observed events. For instance, if during the observed design activity, a student brought up an assignment sheet from class, it was noted in the transcriptions and a copy of the document was inventoried with the strip of action. Finally, in the course of my coding, I composed memos that recorded points of significance that were informed by the research literature I studied along with my data analysis. The preoccupations and themes of this dissertation arise out of the conversation between the field site, its texts, my analysis and the research literature.

**Chapter Outlines:**

The dissertation will not seek to give a class-by-class, group-meeting-by-group-meeting, description of the educating of students’ attention. Instead, I will provide an overview of the class content and discuss my theoretical framework through that description. I want to show attention directed in the lectures, calibrated through the course materials, and performed through design work. The following chapters will look more specifically at themes from TPC and the allied fields of design studies and engineering education. My goal is to show how the design work of these engineering students can help TPC and allied fields refine and rethink topics of framing, non-technical competencies such as judgment, and professional genres. I will then conclude the dissertation with some implications for further research.

The second chapter will describe the course content. I focus on the professor’s lectures, the genres of the class, and the pedagogical approach of the course. I then introduce the theoretical framework in more detail, and describe the process of how students’ attention is educated through lectures and texts to do engineering work like professional engineers. I then forecast an overarching theme of the data chapters by
characterizing the students design work as an activity of attunement. While the engineering classroom is where demonstrations on what and how to attend in engineering design occurs, the practice of attending develops within student groups, where students persuade each other and work together to produce the texts, oral presentations, and visuals for their assignments in a activity of attunement. The process of attunement is a transformation of the material from class into guideposts and resources for design. The transformation occurs as students attune themselves to the emergent tasks and questions arising from ongoing accomplishment of the social order within the team. To attune in this instance means to engage in the practical activity of designing (Ingold, 2002). However, this chapter reveals the pedagogical techniques of the classroom do not translate well to group work, because of the distance between the two contexts. The decontextualized strategies and methods conveyed by classroom lectures and texts are not taken up by students in order to structure the activity of the design group. This chapter offers an explanation of this failure.

Chapter 3 focuses on the activity of framing in a student design team. Framing bounds the phenomena designers attend to; it is an orienting of perspectives to an idea or object. Because design is often not a linear process of problem-solving but a dialectic of defining problems and proposing possible solutions, perspectives are expressed as how a product should satisfy contrary demands. Frames, or more precisely framings, as they are produced and maintained through interactions between designers, are arguments for how to resolve contrary demands. An important type of argument prominent in the students designing is the rhetorical figure of hypotyposis, making the absent present in a vivid and engaging way. Unlike the canonical production through oratory, poetry, or
painting, hypotyposis in design work is a multimodal and social performance that recruits talk, gesture, sketches, and digital images to bring forth an image of a design that may be elaborated and questioned by a group. Importantly, the image is never so detailed as not to allow co-construction or co-design by the group participants. The purpose of framing is not to settle on a design, but to push forth the design process by accounting for more and more contingencies through producing images. An image is not a material construct or object so much as a way of attending and seeing within an on-going dialectic that constitutes the design process. The design itself emerges from this image production in order to frame contextual and technical requirements. Contextual and technical requirements refer to how and where a product will be used and the mathematics and mechanics that make it work, respectively. For TPC researchers and teachers interested in design in the multimodal classroom, this research demonstrates how students invent representations to generate ideas.

The fourth chapter examines how students practice engineering judgments. Non-technical competencies such as judgment are necessary to attend according to the professional demands of engineering. Engineering education, in the wake of research on what students need to learn in their undergraduate engineering courses, has identified several non-technical competencies that students need to develop to be successful professional engineers (Meier, Williams, & Humphries, 2000; Sageev & Romanowski, 2001; Walther, Kellam, Sochaka, & Radcliffe, 2011). One important competency is engineering judgment (Holt, 1997; Robinson, Sparrow, Clegg, & Birdie, 2005). However, there is little research in to exactly how students develop judgment or other competencies through engineering curricula. A related issue is how to define judgment
and what is specific about engineering and design judgment (Davis, 2011). The second data chapter, chapter 4, examines engineering judgment, a fundamental competency engineering educators and industry professionals want to cultivate in students.

Engineering judgment is only vaguely understood, and there are no satisfying definitions of it. However, Davis (2012) provides an exhaustive exploration of what a definition must account for, coming to the conclusion that engineering judgment may be understood as the ability to creatively discern options and necessities while under constraints. My purpose in this chapter is to see how students judge their engineering work. I specifically examine how students working on a mathematical formula determining the amount of wind force a solar tracker should be able to withstand. It is in this kind of scenario where students start to practice what we understand as engineering judgment. I observe how students used their embodied everyday experience to complement the mathematics for determining force. Students imagined what it would be like for different objects to hit a solar tracker to determine whether their calculations were accurate and reasonable. For instance, they imagined a scenario of a bus and a car hitting the solar tracker in order to gauge whether they should design a tracker to withstand a similar certain amount force.

By thinking of wind force in terms of heavy objects striking the hypothetical solar tracker they were able to visualize the effects of their mathematical calculations. In other words, they made the numbers concrete by imagining them as heavy objects. Students learn and practice engineering judgment in the absence of engineering experience by falling back on ordinary reasoning, like testing the results of mathematics through imaginative counterfactual scenarios. For TPC and engineering education researchers who are invested in instilling disciplinary judgment in students, the chapter identifies how
judgment is developed by creating counterfactual scenarios to test results and looks toward how we might get technically minded or CAD tutored students to think outside of algorithmic thinking, the idea that a formula or technology can be assumed to give judgments rather than simply information. With this analysis, I hope to show how attentional activities scaffold the development of students’ competencies.

The preceding chapters and discussions could be conceived as the examination of the work that goes into composing a genre. The fifth chapter of the dissertation looks at students’ feelings and attitudes towards genre work in engineering. In interviews I was told by participants of their frustration with the new genres failure to capture the hard work they put in and the extent of their knowledge about their designs. In what was the first design project for many of the students, and certainly the longest and most labor-intensive design project any of them had hitherto undertaken, students were asked to present their work in a presentation that included several typical engineering texts. The student presentations were presented through PowerPoint and were given by several members of a group. These texts displayed the decisions-making processes and conclusions of the group in regards to make/buy decisions, analyses of potential failures, cost, group member responsibilities, a theory of operations, and CAD design drawings. While these genres sought to reveal the dynamics of the groups’ activities and the groups’ adherence to the demands of the professionalizing classroom, they necessarily constrained the students’ expression of their design as they conceived it. These generic constraints may shed light on a side of genre learning not often discussed. That learning a genre shapes knowledge and activity is widely understood (Bawarshi, 2003; Tardy, 2009); but what about the kinds of attitudes and motives towards engineering practice
that are reformed, recalibrated, transformed, or stripped away as students move forward in a process of professionalization? This chapter describes student views of genre composition. The views expressed by students show that student conceptions of design and engineering communication are at odds with the kinds of ideologies genres structure and transmit.

In technical and profession communication, there is an abiding concern over the transfer of knowledge from the classroom to the work students do beyond the university as engineers, technical writers, scientists, businesspeople, and health professionals (Dias et al., 1999). For many TPC teachers and researchers the concern breaks down into issues of whether the writing and communicating done in the classroom will be transferable to the workplace, whether the simulation of “real word” work contexts can be authentic, and whether students can successfully navigate the contradicting demands of writing professional genres in school. This dissertation delves into those concerns by seeing how students are taught to attend to professional practice and the way that attention manifests in design work. If attention is conceived as including embodied ways of selection, collaboration, and performance then the transformational potential and consequences of professionalizing education can be observed and described.
Chapter 2: Attention and Attunement

This chapter provides an overview of EMAE 260 and further elaborates the concept of attention that informs the dissertation. First, I will present the objectives, lessons, and assignments of the class, and discuss some of the key classroom texts and strategies promulgated to students in order to direct their attention to professional engineering’s concerns. Within this discussion, I take the opportunity to elaborate a difference at work between the two types of activity within the class and what it means for attention.

Attention in the classroom has a different character than attention within group work, and this difference becomes clear by comparing how students design and the class prescribes design. These differences are not necessarily opposed, but rather are in tension, as they do not easily map onto each other. The texts and strategies for how to attend to engineering do not easily map onto design activity of the group. The emerging order of the group’s dynamics forms a method of procedure on which the methods from the class do not fit (see Bucciarelli, 1994; Matthews, 2009). In other words, students struggle to bring the classroom techniques of attention to bear on their design process, because the group’s attention is constituted and reconstituted through dynamic interactions that cannot be accounted for and directed ex situ (compare Suchman, 2007). The embodied techniques of coordinated attention are consistent across both contexts, skills such as gaze, gesture, talk, and other mundane ways to establish joint attention and demonstrate perceptual skills for circumscribing engineering content. But the ordering of those contexts produce differences in design work. Situated design does not proceed according to brainstorming rules; the process is much messier and complex. Decisions
are made through judgments no engineering textbook could inculcate. The design process cannot be captured through models or precisely followed according to steps. The contingencies of the design process, the resources available to students, and the particular concerns of the group create a design process unlike what is propagated by the class. I do not say planning and instruction are useless for a situated activity like designing, that one should forego the effort to structure what is contingent and evolving (Sharrock & Button, 2003). Rather, my goal is to show TPC teachers, engineering educators and design theorists what their plans and instructions look like in action in order to approach future iterations of design education and theory with a better understanding of how textual structures of attention are or are not taken up.

A consequence of this goal is to rethink current notions of learning and expertise through attention. In response to the data, I call how students are taught to design in class an education of attention, (borrowing the phrase from Gibson [1960]) or sometimes attention for short, and how they learn to design by actually doing designing, attunement (Ingold, 2002). Theorists of the perceptual changes novices undergo to become experts consider the process as one process without much interest in accounting for the different situations where that learning takes place (Fountain, 2014; Goodwin, 1994; Grasseni, 2007; Lymer, 2009; Stevens & Hall, 1998). Granted, their studies take place in situations where teaching and practice are nearly simultaneous, such as the anatomy lab, the archeological field site, the design studio critique session, or the tutoring session. In these spaces is a dynamic where classroom instruction is quickly or simultaneously put into action and the progress of implementation is verified and guided by experts. However, every teacher knows that a change of scene and lapse in time can make all the difference
in a student’s work. Simply think back to the times whereupon receiving student work, you said to yourself, “This isn’t what I asked for.” What happens to directions and class content in the hands of students? This dissertation suggests class material is negotiated, worked over, reprioritized, ignored, and misunderstood within and through practical engagement with the assignment itself, which I call attunement. I will describe the difference between classroom attention and group work attunement in the course of describing EMAE 260.

**EMAE 260: Topics and Procedures:**

EMAE 260 answers the call for design to be the central part of engineering education, a call that started in the late 1990s in response to industry concerns about students’ lack of practical engineering knowledge (Akera & Seely, 2015; Dym et al., 2005; Froyd, Wankat, & Smith, 2012). After World War II, engineering education focused on engineering science, promoting technical and scientific skills often at the expense of hands-on practical knowledge. After the Accreditation Board of Technology and Engineering (ABET) changed its accreditation process from quantitative measures of assessment to outcome-based assessment, educators turned towards design courses to meet the new diverse requirements in Criteria 3 of the ABET requirements (Froyd, Wankat, & Smith, 2012). Design courses provide students the opportunities to apply their budding mathematical, technical, and scientific skills to “real” problems, and in the process, meet ABET requirements for learning decision-making, teamwork, communication, applied knowledge, and ethical standards. Traditionally, design was taught in a capstone course at the end of the engineer’s education, and later curricula added a first year or cornerstone course to introduce beginning students to problem
solving and the tools of engineering earlier (Atman et al., 2014; Dutson et al., 1997). More recently, universities have attempted to integrate design throughout an engineer’s education in order to centralize design as the core of engineering (Atman et al., 2014; Friessen, Britton, & Taylor, 2005). These courses are required for some majors, such as mechanical and aerospace engineers at Midwestern University, and for other majors it is an elective. For instance, the EMAE sequence is an elective for biomedical engineers which they may take in addition to their required capstone design courses.

EMAE 260 is part of the integrative model for incorporating design into engineering education. EMAE 260 is a part of a three design course sequence for mechanical and aerospace engineers, but is open to all engineering fields. Outside of mechanical and aerospace engineers, the class is attended by many biomedical and biomechanical engineers and a smattering of other engineering students. When asked why many biomedical and biomechanical students join her class, Dr. Connolly speculated that these students needed marketable skills and the design course provided them experience with designing, managing a project, and working in teams. According to her, the market for biomechanical and biomedical engineers had not caught up to the supply from universities (though she augured it eventually would), so many students were advised to take the design course for marketable skills useful for positions within engineering firms.

As explained in the introduction, EMAE 260 is the second of a three course sequence introducing students to the tools, methods, and concerns of design. EMAE 260 was only two years old when I started my fieldwork. Previously, design education had been relegated to a capstone course. Dr. Connolly, a PhD in Material Science with
nineteen years of management experience at a local manufacturing company, taught both EMAE 260 and the following course EMAE 360. The capacity of the class was uncapped and the course enrolled from 60-80 students a semester. She is assisted by two graduate TAs each semester, but their roles are relegated to grading, and in my two semesters of observation, first in a pilot study and second in the target study, only one class was taught by a TA. And he simply showed a video of a TED-esque talk from a software engineer turned CEO.

EMAE 260 carries a heavy content load for one course. In addition to teaching students the design process, there are also lessons on the science of materials, engineering economics, mechanical testing, risk assessment, manufacturing methods, and several other topics. These topics are presented along with the topic of design because they are integral to the design process at the professional level, though in the classroom, they are not substantially integral to the design process. These topics still are an important part of the course because many students will not be exposed to them before they leave college. Dr. Connolly regretted this state of affairs in her lectures, often noting while broaching one of the above topics that EMAE 260 should have been split into two courses, and perhaps engineering economics should be its own required course. Such a suggestion is easier said than done, as Dr. Connolly knew, because engineers who already have notoriously heavy course loads and are expected to participate in internships and cooperative learning opportunities in their college years, have little space to add two or more classes. The consequence of such a content packed course meant the classes moved quickly and important information was sometimes rushed over. Although, Dr. Connolly held students accountable for all of the content through homework, quizzes, and tests,
design was the focus of the course, and lectures on topics not discussing the design process were not as well attended.

The lectures initially focused on the early stages of the design process. Dr. Connolly would deliver the lectures at the front of the class with a large screen behind her. Her preferred method of lecturing was through Power Point slides. She would introduce a topic, elaborate it through slides, summarize or expand upon the information on the slide, and then often illustrate the concept with an anecdote from her work experience, a well-known case study, or a related issue in current events. Seldom did students ask questions, and often Dr. Connolly did not have an opportunity to initiate discussions due to the amount of content and the constraints on time, the class being only fifty minutes long.

From an introduction to the design process, the course had units on project management, all of the stages of design from conceptual to detailed design, decision-making, manufacturing methods, engineering economics, universal design, product lifecycle, risk assessment, quality control, and basic material science. Dr. Connolly sought to populate student’s frame for design thinking with the many considerations they would have to contemplate in professional engineering practice. She thought of it as “inoculating” students to concepts and concerns they would need to be familiar with in their professional futures. By inoculation she was not referencing the derided conception of teaching students once and then thinking the information need not be reinforced. Rather her conception was more sophisticated, and used inoculation as a metaphor for her hope that since students had been exposed to these concepts and concerns, when they encountered them in the future, they would recognize them and know how to proceed.
With the bulk of their students’ studies taken up with learning immense amounts of technical, mathematical, and scientific information, topics such as quality control and universal design are not assured a place in a student engineer’s education. But, Dr. Connolly believed by introducing these topics, students would recognize them as within the engineer’s purview, and know they would require their attention in the future.

The various units and the lectures around them foregrounded the design process as unique and integral to engineering, setting them apart from the observational and theoretically minded scientist on the one hand, and the practical and technically minded technologist on the other. The focus on customer needs that was consistently emphasized throughout the course, was balanced with a recognition of turning those needs into technical information in order to communicate with other stakeholders in the design process (the focus on technical details/mathematics is discussed in chapter 3). Dr. Connolly also used her personal experience in industry to highlight the kinds of conundrums that may arise in professional engineering. Engineering procedures were often grounded in discussions of industrial applications, how (say) engineering economics or quality control manifests in the work of an engineering firm or company. She illustrated best practices of design with reference to case studies and used the then crisis at General Motors over faulty ignition switches as an unfolding example of the necessity of thinking ethically and communicating circumspectly.

The content of the lectures was a mix of original research and summaries of chapters from Dieter and Schmidt’s (2013) textbook *Engineering Design*. Dr. Connolly offered an expansive view of each topic, showing students different ways of conceiving of topics or the various procedures for completing a task. In her introduction to design,
for instance, she defined design three times through three different citations. She provided five different schematics for design, everything from what she called a “design swamp,” which was a tangle of trajectories from nine different points, to a methodology schematic mirroring the scientific method. Additionally she gave an overview of each phase of the design process and examples of design methodologies. The amount of slides for each presentation varied from the well over forty to fewer than twenty. Often, Dr. Connolly would run out of time and continue a discussion in the next class, or even forego material if time did not allow. No matter what she was able to get to in class, Dr. Connolly regularly reminded students of their responsibility for knowing all the information on the slides, which were posted on the course management platform BlackBoard.

**EMAE 260: Strategies and Methods for Attention:**

The Introduction detailed the description of attention operating in this dissertation and how it points to not only what students attend to but also how. In EMAE 260, students primarily are taught to attend to constraints. Constraints are a considerable preoccupation of design engineers (Buchanan, personal communication) and they were a considerable preoccupation of EMAE 260. In a lecture early in the semester, Dr. Connolly offered a definition of constraints she attributed to ABET as “what is allowed, what conditions MUST be satisfied (emphasis in original).” She also quoted ABET’s examples of constraints, “economic factors, safety, reliability, aesthetics, ethics, and social impact.” Constraints are both given and discovered in the course of the design process. For groups doing (say) the solar tracker, immediate constraints were in the form of performance requirements spelling out just what a proposed solar tracker should be
able to do and where it should go. But other constraints such as customer requirements, cost, environmental impact, and aesthetics were discovered and delineated within designing itself. Constraints are made by students through a research exploration of what is possible and feasible with available resources and time.

Constraints in EMAE 260 are also important for frustrating students’ habituated approaches to doing engineering work. Not only are students now applying their scientific and mathematical knowledge to novel and contingent circumstances, they are learning to propose ideas that are sensitive to concerns greater than novelty and technological capability. In other words, constraints push students to think about engineering for the sake of ends they themselves do not hold dear. Having students fail in this endeavor is major motivation of the class, because it breaks down student-centered thinking, by which I mean students’ focus on expressing their own ability in order to secure the grade they want, and opens up their work to professional concerns of designing for customers and industrial hierarchies in typical, orderly, and ethical ways. This feature of constraints will become a crucial factor leading students’ sense of frustration with the genre work they do for their final presentations discussed in chapter 5. The misalignment I discuss below, however, is specifically about the transmission of strategies and methods from one situation to another and the misalignment that ensues.

Students are taught how to attend to and with constraints through strategies and methods to aid in inventing, clarifying, prioritizing, and deciding. These strategies are encapsulated in texts and displays that structure the composition, activity, procedure, and time management of design groups. These strategies are laminated over each other to form a trajectory from problem definition to the communication of the new product. The
The design process lays out the stages and points of iteration students must go through to design a deliverable product. Within this process is a further decomposition stipulating the procedure of each stage. Some stages are more detailed than others. For instance the conceptual design stage had within it a scheme describing the operations through which concepts had to pass (see Figure 2.1). Furthermore, operations within the stage itself incorporated multiple strategies for inventing, arranging, and deciding.

**Figure 2.1: Slide from Concept Design Lecture**

The attention structuring properties of EMAE 260’s strategies and methods may be understood through a focus on the Gantt chart (see Figure 2.2 for an example). The entire design process is structured temporally through a Gantt chart that segments the process according to the time allowed for its completion, namely the school semester. The Gantt chart works by representing tasks to be completed along a trajectory displaying the time allotted to each task. Each task’s allotment of time is governed by how long it is expected to take to complete, which tasks are competing for the same time/space, and the
resources available to devote to the task. The design process is configured temporally, which in turn is represented spatially through the chart, forming a text that structures when, how, and how long designing should be. As Yakura (2002) discusses, Gantt charts (and I argue other attentional texts as well) are interesting because they decontextualize and direct thoroughly contingent and situated enterprises. As such they have to be flexible while still maintaining their authority and persuasiveness (see Henderson, 1991; Star, 2010; and Yakura, 2002 for discussion of these types of texts as ‘boundary objects.’) Henderson (1991, 1999), for example, discusses these types of texts in terms of their flexibility, making them useful to different members of an organization.

But they can also produce tension when they serve as directives rather than resources for directions. Or rather, for EMAE 260, these texts went unused because they were not taken up as resources, and were instead viewed as requirements to be met. Students’ relationship to the Gantt chart exemplified this issue. They adhered to their Gantt chart to a certain point and then as their design process diverged from the approved design process established through their Gantt chart, they started to keep two timelines, so to speak. The Gantt chart they displayed to the professor during presentations showing everything was going swimmingly, and the ad hoc timeline they used to deal with what was yet to be done. This timeline was updated weekly, re-inscribed in emails, on whiteboards, and verbally exchanged. This was the ‘real’ timeline that never made it to Dr. Connolly and was never even finalized.
Here is a rather stark difference between attention and attunement and their interrelationship with texts. In interviews, participants were asked about the purpose and use of the Gantt chart (see Figure 2.2), specifically. Dr. Connolly explained the Gantt chart allowed for her to check whether students were attending to where they were in the design process. She judged this through seeing the changes in the Gantt Charts when students noted their progress at the end of presentations. She characterized Gantt Charts as “living documents” referring to the expectation that they would change with and within the design process itself. But they did not. Groups made no changes to their Gantt Charts throughout the semester. Each chart looked as if every phase had been completed promptly and just as originally planned. For Dr. Connolly, this was an issue because she expected students to understand something fundamental about engineering work through the Gantt chart:

*Prof: They aren't really thinking about where are we in this process. It's like: hey we did our Gantt chart, here it is. It's like; well wait a minute, you gotta mark that, some of these things are going to change. And other things are not [...] it's that moving timeline once it's to the left of the timeline [hence already completed] it's set in stone. It's the stuff to the right you still have some opportunity change*
JSW: So why do you want progress visually displayed, not just discussed in the presentation?

Prof: Because if, otherwise I don't know if they're thinking about and talking about it. It is the demonstration of their understanding that is part of how this all goes, that basically at any point in time all we got is the work done at this point which sets the preconditions for what happens next. If you pushed that work to here [hand placed posteriorly on sagittal plane] then you got a timeline that is shrinking [palms nearly touching]. So you know, what are you going to do? Is everybody gonna get together that weekend after Thanksgiving and put the whole thing together?

As a textual instantiation of the design process, the Gantt chart orders the work of the group. Additionally, the Gantt chart’s structure allows students to visually demonstrate the compromises and sacrifices they have made as a result of unforeseen circumstances. It shows the professor the workings of the group and how they understand time management, how well they prioritize, and their facility with one of the primary tools of engineering design. The Gantt chart is more than just a representation, it is a tool, a tool that affords a picture of progress and a future trajectory (Roth, 2104). And most importantly a tool to reimagine that trajectory through a reconfiguration of progress. That point, however, did not come across to students. They saw the Gantt chart as a representation of the way they were supposed to appear to Professor Connolly. In the course of their activity, timelines and tasks were shuffled around, but the tools to manage that shuffling were not incorporated. And this was not unique to the Gantt Charts. As I discuss in later chapters, this happened in various ways with brainstorming techniques, the Pugh method, and the final presentation.

The attention directed and structured by the lectures and through texts like the Gantt chart was not taken up by the groups, and failed to regulate the activity of designing. I ascribe the misalignment in part to the nature of the class. Design is a
practical activity requiring engagement with constraints and emergent problems. EMAE
260 provides for that kind of learning, but the manner in which information is transmitted
does not translate into practice; there is a gap between the attention taught in the
classroom and its uptake in group work that is due to the way skills are developed and
knowledge becomes concrete.

The Education of Attention and Attunement:

I investigate this problem by reconceiving of design work as attunement. I
illustrate attunement by way of analogy to Ingold’s (2001) argument against approaches
in evolutionary biology and cognitive science to learning. I focus here on Ingold’s
characterization of cognitive science, wherein he discusses then prevalent notions of how
information/representation/knowledge is passed from one person to the next. Ingold holds
that cognitive science mistakenly understands the transmission of knowledge as similar to
thinking a cookbook transmits knowledge rather than simply information (p.137). For
Ingold, cognitive science assumes that once information is processed by the mind through
inscriptions it is knowledge simply awaiting conversion into behavior. Cognitive science
underspecifies this conversion process, which in turn, underwrites the mistake of
according information the status of knowledge. Ingold counters by pointing to the
conversion process as what actually makes knowledge, not the processing of the
brain/mind:

The conversion, however, is easier said than done. No known cookbook comes
with such precise instructions that its recipes could be converted into behaviour
just like that. When the recipe instructs me to ‘melt the butter in a small pan and
stir in the flour’, I am able to follow it only because it speaks to my own prior
experience of melting and stirring, of handling such substances as flour and
butter, and of finding the relevant ingredients and utensils from the various
corners of my kitchen (Leudar and Costall 1996: 163). The verbal commands of
the recipe, in other words, draw their meaning not from their attachment to mental
representations in my head, but from their positioning within the familiar context of my activity in the home. (Ingold, 2001, p.137)

Knowledge is enacted through the activity of performing tasks. The recipe is meaningful because it directs the cook to perform familiar actions built up through prior experience.

In other words, knowledge is acquired through skill, not the mental representation of information. Learning to acquire a new skill, then, is a “movement of attention” where an individual takes up an activity by responding to the perturbations of an environment (p. 136). To cook a dish, one leans on earlier acquired skills of mixing and chopping, the nearly tacit knowledge of knowing when food is ‘done’ or ‘ready’, and the mechanics of the stove. To bring the dish to completion requires a management and deployment of these skills, and to succeed at the dish, one must have expertise in this management and deployment. The cook must attune her body to the kitchen and enact the recipe (p. 139).

I distinguish between attunement and an education of attention by designating an education of attention the process and purpose of the class lectures and their textual extensions, and attunement as the process of enacting that attention within a context distant in time and space from where the instruction was given or conceived. The distinction accounts for the tension observed between the attention taught in the classroom and the performance of designing in group work.

The analogy I would like to draw matches Ingold’s characterization of cognitive science as the transmission of representations with classroom attention and his notion of attunement with my idea of attunement in group work. As detailed above, the lectures and texts provide resources, strategies, and methods to structure and circumscribe students’ attention to the work of professional engineering. They are transmitted via talk, PowerPoint, and Blackboard, and students are to use these texts and their lecture notes to
design a product. The result is somewhat like someone cooking Mornay sauce for the first time without much more knowledge than how to turn on a stove or perform an action that works well enough for mixing. Something like Mornay sauce may be produced, but the activity it takes to get to that point will not resemble an expert or even competent performance of cooking. In other words, transmitting detailed instructions may be effective to a point, and it would be too strong a contention to say that the cognitive science understanding of learning is bound to fail. It is not. In the following two chapters, I recount performances of framing and judgment that resonate with research on expert performances. However, the chapters also demonstrate a failure to take up the strategies of the classroom because they either underspecify the skills needed for successful performance, or the strategies fail to graft or fit to the emergent social order of the group. Either way the process of professionalization is stymied by relying on a transmission of representations to impart design knowledge.

One will object that the design classroom with its focus on learning through problem solving under “real word” constraints accords well with attunement. Students learn the design process through practice; design knowledge is not simply transmitted. And of course that is true, but even such a structure has its issues, as this dissertation details. Students do not utilize the tools for structuring attention because these structures are necessarily deficient, being as they are decontextualized. They are decontextualized in the sense of not accounting for the identity of participants, the particulars of the problem, and the environment in which the process is to unfold. A decontextualized text is not a problem because it lacks specifics; it is a problem because it does not allow for its practical enactment by lacking the means for participants to perceive correspondences of
its (the structuring text’s) procedures to a specific situation. To harken back to an earlier example, the manner and skill of implementing the recipe in a kitchen is left tacit, which is a problem for one who does not know his way around a kitchen.

But that is what these structuring texts do, one might say. ‘They are plans, like the example of the patent in the Introduction. Are they not demonstrations of not only what to attend to but how? The object of the patent is revealed through what Csordas (1993) calls a “somatic mode of attention,” when the body and world make available an object for practice (pp. 136-138). To return to the cookbook, this is not only the ingredients of the Mornay sauce, but how to mix them. Do not the brainstorming methods, the Pugh methods, the decision trees, and Gantt charts demonstrate somatic modes of attention? They do, but in the learning process there emerges a social order accomplished and responded to by and with participants, creating a counter mode of attention that contends with the textual mode. In other words, situated attunement pushes back on the structures of texts, and in the case of the group I observed, marginalizes the structures of classroom attention.

The social order of any particular group is the embodied, discursive, textual, actions that cohere the group in the furtherance of a practice. These actions not only cohere the group, but in turn, constitute the group’s definition and purpose. So when I talk of the social order of the design group, I refer to how what they do defines what they are about. Social order is an emergent accomplishment of participants; it must be choreographed and maintained through attending (Clark, 1996; Oakley, 2009; Tulbert & Goodwin, 2011.) The action of social order (extrapolating from Ingold [2001]) relies on experience and skilled behaviour. Working in teams, making decisions, sketching, and
using tools are all skills as well as means to constitute and accomplish a social order. The textual structures of attention from the classroom do not transfer to group work because they are difficult to implement without the underlying skills or experience. As students go about the work of designing, they develop their own ways of accomplishing their goals or in some cases, allow themselves to get carried away in settling some point of contention. These inevitabilities impact the education of attention. Scholars of the connection between learning to see and manipulate objects of professional practice and becoming a professional gloss over this impact (Fountain, 2014; Goodwin, 1994; Lymer, 2009; Prentice, 2013). This is not necessarily an oversight, but more of a result of choosing to look at situations where novice and expert are in close proximity.

Part of this deficiency may be addressed by looking to Rhetorical Genre Studies (RGS) for guidance on how to trace the uptake of texts in distal contexts (Rousanville, 2012; Russell, 1997; Russell & Harms, 2009; Russell & Yanez, 2003). But with few exceptions (e.g. Brandt, 1992; Prior, 1998; 2004; 2010; Prior, Hengst, Roozen, & Shipka, 2007), the uptake process in RGS is not the “taking up process” that close analysis of situated writing and composition reveals; RGS scholars often do not get to the level of understanding the reading practices and judgments that configure and position texts for social action. RGS would see the genres of the classroom mediating the activity of the group, but the actual physical acts of selection and representation are obscured by an unwavering focus on texts (see Russell, 2010 for an implicit recognition of this tendency) or an interest on the part of some researchers in furthering the conceptual vocabulary of activity theory (see Spinuzzi, 2011; 2012 for two examples, and Suchman, 2000 for a critique from the perspective of ethnomethodology). What is needed then is a
look to see how taking up is or is not accomplished in educational contexts that are distant in time and space. Theoretically, ethnographic research in both professional learning and RGS has taken it as gospel that situation and context make all the difference for activity. What remains to be investigated is the difference social order and skill make in the transfer of textual structures of attention.

In order for learning and professionalization to be more effective, alternative educational approaches should be considered. The situation of my field site was particularly difficult because it lacked instructor support. Dr. Connolly was the only person available (her two TAs had no teaching expectations) for EMAE 260 and EMAE 360, and she averaged about sixty students in each course. A lecture and group work with periodic presentations, homeworks, and tests, are what is possible in such an arrangement. It is no surprise to anyone involved in EMAE 260 that the conditions for learning were less than optimal. The optimal arrangement, and the one that I recommend as a goal, should be an arrangement where the instructor acts or has assistants that can act as coaches for the student groups. By coaches I mean a knowledgeable engineer or designer that can attend some design meetings and make recommendations for practice. A person to manage a design group and make suggestions for implementing decision-making strategies or to point out ethical considerations, provides students with in situ instruction in the course of designing, but also a model of judgment to imitate. As I detail in chapter 4, a constituting feature of design is when and how to apply past experience and technical, mathematical, and scientific knowledge to emergent concerns. Students, for the most part, lack facility with appropriate application, so someone who takes up the stance of a coach, that is, someone part of the team, but not playing the game to the same
degree as the players, could provide the direction students need.

In my conclusion, I will survey the findings of the three data chapters and revisit the question of coaching through the lens of writing pedagogy as articulated by Bean (2011) and my own pedagogical experience teaching a business and professional writing class to design a website. I hope to offer a clearer picture of coaching and enumerate more of its benefits. Now, I will take an in-depth look at the practices of framing, judging, and genre writing to understand how these things are accomplished by students, how they differ or are in tension with the strategies and intentions of the classroom, and what they can tell us about how student engineers learn to attend like professional engineers.
Chapter 3: Representation in Engineering Design Practice

In carrying out the design assignment, students must first establish just what the assignment is. They meet as a group and discuss all the parameters and constraints specified by the professor in the assignment sheet. The group I observed was assigned the task of designing a solar tracker, a mechanical device that orients solar panels to the sun’s position, for Southern Ontario. The solar tracker was to be a dual axis tracker (meaning it could both follow the diurnal and seasonal tracks of the earth around the sun), need little maintenance for a span of 7 years, support four 240 watt solar panels, and withstand the weather conditions of Southern Ontario. The assignment spelled out these specifications and not much else.

The students, then, needed to understand and develop their design concept while attending to these constraints. But the constraints themselves were only stated, not detailed in the assignment sheet nor in the lectures. Students had to answer for themselves questions such as: What are the weather conditions of Southern Ontario? Who would want or need a solar tracker in Southern Ontario? Even, where is Southern Ontario? Students needed to research the setting and situation for which they were designing, determining data points of topography, geography, population, and more. Simultaneously, they had to answer technical questions such as: how much do solar panels weigh? How do dual axis solar panels work and what kinds are there? How does one ensure that a solar tracker is nearly maintenance free for 7 years? What does a solar tracker look like? Students quickly realized that technical questions and what I call contextual questions were mutually elaborating. For instance, the height, angle of rest, and materials of the solar tracker would need to withstand the snowy winters of Southern
Ontario. The placement of the solar tracker, whether on the roof of a home or in clear area of land depended on who they targeted as customers; either residents of (say) Toronto or people living in more rural areas. The two concerns, technical and contextual, were most tightly interdependent in establishing the track of the earth’s movement around the sun at different times of the day and year from the terrestrial perspective of southern Ontario and coordinating the positions and movements the tracker would need to achieve to be energy efficient. When students consider these kinds of questions of engineering and environment in relation with still more questions of (say) feasibility and marketing they are learning to attend to engineering problems like professional engineers. The ideal engineer envisioned for the design class is one who can integrate many different constraints into a design, making decisions while taking account of the various stakeholders involved, all while fulfilling the requirements of the project. The students I observed were tasked with developing, emulating, and performing this professional engineer.

These questions and constraints comprising professional engineering are attended to through the activity of framing. Framing in design designates actions that, according to Schön (1983) “bound the phenomena to which [designers] pay attention. Their frames determine their strategies of attention and thereby set the directions in which they will try to change the situation, the values which will shape the [design] practice” (p.309). Frames themselves are attentional structures, built and reinforced by education and context. They are value-laden, theory-laden, and certainly in the case of teamwork, socially constructed. My focus in this chapter will be on the framing actions of students as they attempt to bound the phenomena to which they attend. This bounding is a
collaborative and rhetorical process performed in multiple modes of communication. In order to examine framing closely, I center my analysis on two consecutive design meetings where students begin to address technical and contextual questions as part of the “conceptual design phase,” thus leaving other instances of framing to the side. In a review of the concept in design, I will touch on the many ways this capacious concept has been employed in analyzing what designers do, but in my examination that takes up the bulk of the chapter I want to focus on the particular instances of framing in order to highlight its rhetorical aspects.

I will first further define framing and articulate a perspective that links the discussions of attention in the previous chapter with the present discussion. I will then display and analyze transcriptions from group work I recorded as instances of the modes of framing actions that took place in the course of designing. I examine multimodal framing actions principally consisting of talk, gesture, sketching, and internet searching. I stress how these modes were always combined by students in order to make their inchoate design more vivid and present to the rest of the team. I find vivacity and presence to be key features of framing in design and explore those features further in a discussion of the rhetorical figure hypotyposis, or the act of bringing-before-the-eyes. The chapter will conclude with implications for understanding framing, engineering design, and team writing and add to the body of work in TPC which views rhetorical displays and demonstrations as, in the words of Perelman (1982) "techniques of presentation” (p. 36; see also Gross, 2009; Teston, 2012; Wickman, 2013).

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Hypotyposis is also called enargeia, phantasia, ekphrasis, evidentia, demonstratio, and other terms depending on the context and author.
Framing in Design Work:

This chapter looks into the framing actions of students doing design work.

Framing is a concept in many disciplines such as sociology (Goffman, 1974), linguistics (Fillmore, 1982, and policy analysis (Lakoff, 2004, 2008), and from these and other disciplines, the notion of framing has been taken up in to still more areas of inquiry6. Across disciplines the idea of framing falls into two kinds: framing as both the production and product of linguistic interaction between participants in and with environments, and framing as a mental schema based on prior experience and knowledge (Tannen quoted. in Paton & Dorst, 2011). The concept of framing in design borrows from each kind.

Framing encompasses both preconceived notions and prior values and is a process where participants share their ideas about an object or plan through working with each other and with the materials of design. The combination comes from the work of Donald Schön (1983, 1984), who describes design practitioners framing problems according to prior experience and values. But framing quickly moves to reframing as designs are worked through in discussions with other designers and clients, or through the sketching of ideas, where their materialized designs “talk back” to the designer(s).

Donald Schön (1984) provides a case study that illustrates the two kinds of framing that occur in design work. An architecture student designs a dormitory entrance that is sketched according to a perspective that eschews centralized hierarchy of space, meaning that his design is characterized by “free flow of spaces, continuity, and

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6 See Raedemaekers & Johnson-Sheehan (2014) for an example of the versatility of the concept of framing. In a discussion of how to approach arguments in science, the authors take the concept of framing from political science that originated in linguistics that was then in turn adapted to communication studies, and finally utilized in their paper for the areas of Rhetoric of Science and TPC. Their conception of framing holds that discourse itself is a frame through which attitudes can be engendered.
permeability” (Schön, 1984, p. 134). His professor worries his design will be incomprehensible to critics though the student does not agree. In order to help the student see the potential conflict, the professor encourages him to do more drawing, to sketch out more of the design with the hope that the potential issues will become apparent in further design. What Schön shows us is both the generation and elaboration of framing and the inevitability of reframing as new opinions are offered, new data gathered, new factors considered, and more experimentation is undertaken. Framing in design, then, is both the application and the negotiation of perspectives with design materials and stakeholders. In this way it includes both schemas and interaction.

**Framing in Engineering:**

In general, framing in engineering does not dramatically differ from framing in other design enterprises. Schön (1983) tracks the efforts of engineering students to replicate a color for the manufacture of firearms after the gun manufacturer loses its supply of an ingredient that provided their trademark color on gun hammers and triggers (p.171-176). Schön describes the engineering design as an art and explains that it proceeds in a similar fashion to that of architecture: “a reflective conversation with the materials of a situation but in this instance, the reflective conversation wove its way through stages of diagnosis, experiment, pilot process and production design” (p. 175). The “stages of diagnoses” are framings\(^7\) that (in this case) bring theoretical schemas from thermodynamics and chemistry to bear on various experiments with metals and heating design. Students attend to one way of dealing with the problem, test or reason it out, and then engage in reframing in response to the new data or new scientific approaches. Both

\(^7\) I use “framings” here and other places rather than “frames” to signal the active aspect of how framings come to be, are maintained, and are shifted.
design enterprises include framing as a tactic for bounding each problem in a way that recruits participants’ attention, a way of embodied working with and through materials. What is somewhat occluded in both these examples from Schön is the body’s/ bodies’ role in each of these examples. Sketching, modeling, pointing to features with other people are all “somatic modes of attention,” what Csordas (1993) describes as “culturally elaborated ways of attending to and with one’s own body in surroundings that include the embodied presence of others” (Csordas, 1993, p. 138) that respond to and work in stabilizing frames. Accounts of framing generally are silent on its embodied aspect.

In engineering environments and especially professional engineering environments, framing is the work of many, many people. Bucciarelli (1988, 1994) recounts in several ethnographic case studies the myriad of opinions, concerns and perspectives that must be translated, reconciled, or discounted in order for a product to be “handed off” to a manufacturer or client (Bucciarelli, 1994; see also Vinck, 2003). Frames are built and contested in the exchange of “object world” discourses. Bucciarelli defines “object worlds” as “the domain of thought, action and artifact within which participants in engineering design… move and live when working on any specific aspect, instrumental part, subsystem, or subfunction of the whole” (p.62). In other words, object worlds are the situated perspectives of engineers that are expressed in the design process. The many discourses inevitably conflict and the need arises to create tools and representations that act as frames coordinating the attention of everyone involved at different times throughout the design process. Tools and representations are the “charts, acronyms, sketches, diagrams, models, mock ups, last year’s product line, specifications written out in a contractual document etc.” that temporally stabilize the frame
A stable though temporary frame “serves as a vehicle for negotiation of priorities, fixing what is important and significant, what is less so” (p. 230).

The professional world of Bucciarelli and Vinck’s (2003) respective ethnographies are much more complex than what students face in engineering design course in colleges and universities. Vinck (2003) describes the vast professional ecology of a European engineering firm where a novice engineer is tasked to build a wall at a nuclear facility. The novice engineer spends weeks on attempting to contact and garner assent from people across the world on the precautions and installation of one single divider. The attentional field for his task is stretched to include the crucial input of various engineers, scientists, and regulators, most of whom he had not encountered before. Students by contrast, do not have to navigate such a web of constraints, their sociotechnical system is more intimate. Though design courses simulate professional constraints, input on the design is principally the students’ who do not inhabit vastly different object worlds. However, the fundamental activities that comprise and facilitate framing are similar to their professional world counterparts.

Ordinary actions of chart making, gesturing, sketching, note taking, internet searching, talking, etc., are common to both student and professional engineers’ framing activities. Though the professional workplace may oftentimes be a more complex space in terms of the sheer number of things that will impact design, the same core actions undergirds the practice of both. This is not to discount the situatedness of the two spaces and how it influences the way framing is accomplished; it is simply to point out that inscriptions and talk stabilize frames in the design practice of both spaces. A case in point is Dorothy Winsor’s (1994) account of the textual activities of student engineers in
imagining new uses for a company’s product. Winsor does not use the term framing, but her interests in the students strategies for invention form parallel instances to the kinds of framing detailed above. The students use writing (in an expanded sense) to not only invent possible new uses for the product; they write “to consider ideas communally so they could prompt more ideas in one another and judge the ideas they already had” (Winsor, 1994, p. 241). Winsor’s student wrote different texts to share ideas, stabilize them for the scrutiny of the group, and use them as bases for further invention. Frames, in this instance, are textually materialized to put the group on the same page (so to speak), but they are treated as means to creating new frames, new inventions pushing the design towards a point that responds adequately to the concrete situation within which the group designs.

**Framing and the Art of Design**

The purpose of framing is to establish a perspective on, and by extension, an appropriate approach to a unique problem. Problems in design are “wicked” (Buchanan, 1992) and “paradoxical” (Dorst, 2006). Design problems are wicked in that they are fundamentally indeterminate, lacking definitive parameters outside of the specific design situation. Courses of action for defining and solving problems must be invented in the process of arguing for what is necessary for the design to come into being (Buchanan, 1992). Design problems are paradoxical in that they are discovered in the clash of two or more discourses, such as discourses concerning economics, ethics, materials, manufacturing, etc. (Dorst, 2006). A solution to paradoxical design problems means satisfying all of the relevant discourses to a degree so that a project goes forward. Thus, framing as an approach to a unique problem is not a simple matter of an application of a plan, but rather is a creative (Cushman, 2014; Dorst and Cross, 2001), and social
activity that requires argument to resolve conflicting interests and concerns.

Framing is not something that is accomplished once in designing and then the rest of the work follows on. Framing is a temporary stabilizing of design work that may last for just a moment until a reframing occurs as another argument is offered or perhaps a new piece of data is found (Cushman, 2014). The inchoate design is bound or framed by arguments that position the attention of the designers in particular ways (Stumpf & McDonnell, 2002). In making use of an established task, such as designing a solar tracker for customers in southern Ontario, designers make argumentative moves that use the established task as a background of intelligibility. According to Stumpf and McDonnell (2002), these arguments proceed from shared premises of the group (p.14). They happen rapidly, as well. Stumpf and McDonnell use Perelman and Olbrechts-Tyteca’s (1969) analysis of arguments of association based on the structure of reality, associative arguments establishing the structure of reality, and dissassociative arguments to analyze a transcript of a design team working on constructing a new backpack (Perelman & Olbrechts-Tyteca, 1969, p. 411-442; Stumpf & McDonnell, 2002, p.16-19). They found over 300 frame shifts in a two hour design session (p. 16-17). Stumpf and McDonnell (2002) take for granted that there is enough established in an initial design problem to establish “a reality” or premises of argument from which to makes associations and dissociations. In the design group I observed, even the very premises of arguments were part of what needed framing. I offer that premises for argument are not always pre-established, or more cautiously, not established concretely to support arguments, but rather invented as designing proceeds. Designers use their professional backgrounds, the
brief they have in front of them, input from stakeholders and their own past experience to propose possible avenues for designing. These are acts of selection, bringing forth possibilities to push a design to satisfying many different concerns.

A quick summary of a few minutes of design work illustrates my point. In group meeting early in the semester, I observed a student’s hypothetical proposal for the solar tracker to be mounted on household roofs rather than on the ground. This proposal bounds the problem of the solar tracker to a particular situation, a reality that must account for a host of different factors: What are the weight-bearing properties of a typical domestic roof? Which likely materials are light weight, sturdy, and cheap enough to do the job? Can a dual axis solar tracker be efficient when affixed to the slope of a roof? Arguments for or against this possible placement of the solar tracker shift the inquiry into a new context as the students attention shifts in the form of new questions, new internet searches for relevant patents, and new hypotheticals about the potential problems of a roof mounted tracker.

When a proposal or sketch is made for the design, what is being actively brought to the group’s attention is a rather complex idea. In one sense, the idea is visual. The tracker is formed by its placement in a context, a description of its mechanism and function. But concurrently the idea is a correspondence between the different concerns that are at issue. The proposal of a roof top tracker calls form an image of a solar tracker on a roof that is an indexical sign satisfying the many discourses that are at play in the group discussion, like efficiency, installation, maintenance, and cost (Medway & Clark [2003] calls the process an “envelope of coordinates” [p. 270]). Framing is an activity of finding what is appropriate for a shifting situation composed of various different concerns.
and discourses. For an idea to be accepted, for a frame to be established, it must survive the continuing barrage of competing frames and the contingencies of the design process, contingencies that only come to be as design proceeds in its situatedness. This state of affairs largely accounts for what Richard Buchanan and others have described as the fundamental indeterminacy of design (Buchanan, 1992; see Coyne, 2004 for a postmodern elaboration).

So how do designers do it? How do they bring forth compelling framing arguments and what kind of arguments are they? What do they reveal, to what do they try to gain adherence? My investigation of these answers in the design of activity of engineering students is informed by the reflective practice theory of Donald Schön (1983, 1984), the design as social process approach from Louis Bucciarelli (1988, 1994, 2002), and the recognition by Richard Buchanan (1985, 1995, 2001) and others (Fleming 1997, 1998; Lloyd & Busby, 2000; Stumpf & McDonnell, 2001) that the design process is thoroughly rhetorical. Though these perspectives have different emphases, each notes that technical rationality, technological determinacy, and scientific methodology offer little in the way of an adequate explanation of how designing works. Each also emphasizes, though to varying degrees, the situatedness of design work, how its processes and outcomes are interwoven with its local organization (Lynch, 1993, p.125-133). In summary, I examine the rhetorical, social, and material ways design framing is performed, and what framing says about how the students I observed design.

The next sections investigate what exactly students do to frame group activity. The data are from video recordings of students working together in a group. At the point I focus on, students are beginning the so-called conceptual design phase of the assignment,
where they generate ideas for the construction of the solar tracker. I shall concentrate my investigations on how they argue for their ideas, specifically the modes by which they argue and what those modes accomplish. I concentrate on student designers’ talk, their gestures, their sketching, and their internet searching. I find that what students do is try to create a vivid image of their idea that is not only imaginable to the rest of the group, but also answers or is amenable to the various concerns circulating in the design discussion (Nelson & Stolterman, 2003). Specifically, I look at how students bound the idea of a solar tracker for their group’s attention and offer analysis on the fact that these acts of bounding are both vivid and fitting.

**Framing the Solar Tracker for Students:**

Before looking at how students enact frames it is important to note how they understand framing as a concept. Professor Connolly did not make explicit mention of framing as I have described it above, but she did lecture on closely aligned concepts. Early lectures of the course spelled out in great detail the conceptual design phase, the phase where the invention of possibilities is most prominent due to the lack of a settled design approach. Theses lectures hewed to the trajectory of the Dieter & Schmidt (2013) course textbook. Professor Connolly’s Power Point sides were often summaries of the relevant material in the textbook, but in her lectures she often expressed the fruits of her own professional experience. She emphasized to students how technical requirements for designs must be traced back to customer requirements. The customer as a person or organization is always spatio-temporally situated and has a purpose to achieve. Furthermore, there are economic social, environmental and other factors that further delineate what the customer or organization needs and desires. In a design brief, like the one Professor Connolly provided for her students, some description of the customer is
made and some constraints are specified, but it is up to the students to generate actual, concrete customer requirements and then turn those requirements into technical requirements for design work. Professor Connolly’s perspective on design framing demonstrates the interdependence of what I called at the beginning of the chapter, contextual and technical concerns.

Though Professor Connolly often discussed technical requirements being “derived” from customer needs, in that order, her Power Point slides and her insistence on design as an iterative endeavor brought to students’ attention that designing products is not a linear process, but a iterative one that necessitates going back to previous points of idea generation, decision making and inventing anew. Professor Connolly was adamant, however, that requirements be derived before students sketch designs. She pointed out that having requirements prevents, among other things, “scope creep,” the notion that through the unchecked accumulation of contextual and technical concerns, a problem takes on more and more dimensions and becomes unwieldy. Requirements serve as an early frame for designing in that they give designers something to fulfill and reference. Requirements do not determine the design, however, as possibilities for their fulfillment are yet to be explored.

Professor Connolly provided the students textual tools to structure their activities and how to design like a professional engineer. For instance, in a lecture on formulating requirements, the professor provided function decomposition diagrams to get students to identify and breakdown the functions and subfunctions, inputs and outputs of their assigned products. Creating such diagrams, as the textbook states, “results in a solution-neutral representation of the product called a function structure. This type of
representation is useful for generating a wide variety of design solutions” (Dieter & Schmidt, 20013, p. 218). The diagrams aid students in understanding what the composition of the product is without proposing solutions. The act of making such a diagram textually orients within a field of functions that serve as topics for invention, and so does the many brainstorming techniques, and decision-making matrices Dr. Connolly offered to structure attention to design work. Professor Connolly lectures and the strategies she imparted present the means for organizing the group’s joint attention, while simultaneously demonstrating a professional skill that selects what matters in preparing design solutions for engineering problems. Framing, then, is a professional skill.

The students followed the professor’s directions for deriving technical requirements from customer requirements, however did not adopt, for instance, the brainstorming strategies the professor suggested. Their one attempt at brainstorming quickly broke the rules and became unregulated design discussion. However, the students did establish an understanding of framing from a discussion of what was on the Gantt chart for the coming week’s meeting, Benny asked Bob in front of the group what “reframing” meant? The Gantt chart specified reframing as part of several activities that were to be reviewed for the next meeting. Bob answered:

Bob: “So we started with the initial problem statement, right, which she gave us. So now what we did is reframed it to see what we want to focus on and so now we need to do further research into want that means.”

In response to Benny’s question, Bob lays out a vision of framing for the group. The initial problem statement refers to the assignment sheet and the parameters Professor

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8 There will be a discussion of the consequences later in the chapter
Connolly presented in class. The reframing that was done refers to the process of delineating further some features of the design and some information on the customers they seek to satisfy. Some things that were settled was whether the project was feasible, whether the tracker should be an active dual tracker design or a passive design, and whether it should be marketed with the rural or suburban resident of Southern Ontario in mind. These framings become aggregated and stabilized through meeting notes, the movement of joint attention to the next week on the Gantt chart, the delegation of further research and sketching to group members for the next meeting. The uptake of the frame depends on concerted action on the part of the group and this uptake takes many forms. However it may happen in a particular situation, contextual and technical concerns are fit together and the design is clearer, a little closer to emerging. At least that is the trajectory of the activity the group sets for itself. But Bob reminds the group that further research is needed, framing and reframing will continue as the object of the group’ focus, the design itself, is pushed forward into actuality.

Learning how to frame problems is similar to the inculcation of professional vision, embodied and textual ways of seeing and understanding objects according to the practices and ideologies of a profession (Goodwin, 1994; Lymer, 2009; Styhre, 2010). Students and young professionals are taught to see objects with professional eyes and categorize them according to professional standards using professional tools. Furthermore, in professions that address clientele, part of the learning of professional vision means understanding not only how professionals see and make objects of practice, but also understanding how non-professionals view the labor of professionals. Students in architecture, for instance, not only learn to see their design from an architect’s
perspective; they are also pushed to see blue prints and floor plans from customer perspectives: how customers will make sense of and use the space and dwellings they create (Lymer, 2009; Styhre, 2010). Learning to frame engineering problems, how to use the tools and phases of design like a professional engineer, shares characteristics with professional vision, such as the use of texts to decompose phenomena for professional scrutiny and selecting features of material to create new representations. It differs from professional vision by focusing not on re-describing phenomena, but on generating a different way of attending to phenomena. The move to classify, and demonstrate skill or authority is not an end in itself with framing, as it is with professional vision. Frames or framings invent new phenomena, or more precisely, new ways of attending to phenomena to solve contradictory demands, and in the next sections I examine several modes where students rhetorically attempt to give their frames presence.

Image Making:

In the design meeting following the establishment of several design parameters mentioned above, the group convened to further specify to whom they were trying to market the design, the angles of the earth’s path around the sun in southern Ontario, and to discuss preliminary sketches of concepts in a brainstorming session, among other things. These initial discussions were predominantly verbal. The students’ talk was grounded in reference to earlier framing materials and activities. The assignment sheet from the teacher, the Gantt chart that, at this point in the design process, still specified

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9 Professional vision and related notions like “trained vision” (Fountain, 2014) can be and sometimes are more than taxonomic inquiries. Consider the defense’s re-description of the videotaped assault on Rodney King into a new narrative of professional police practice (Goodwin, 1994) or Fountain’s (2014) description of how students use their trained vision in dissection to make cadavers anatomically “beautiful.”
what their meetings would consist of, and the delegated duties of the group, provided starting points for the students’ talk. Topics of talk started to spread out beyond what the past framings had specified as the students became immersed in the discussions with each other, research, and realizations of the extent of consideration that emerging problems require. In other words, frames constrain designing (Bucciarelli, 1994, p. 85), but through exploration, gaps in group knowledge and accounts are made apparent (Medway & Clark, 2003, p.264), which requires reframing.

Framing and reframing comprised the vast majority of the students’ design activities. Through nearly 11 weeks, the group would gather together in different study rooms across the campus to design. From the earliest meetings to the day before the group was to present their design to the professor and their classmates, the students presented ideas to each other on making a novel solar tracker for the rural residents of Southern Ontario. Doing so meant thinking about tracking the sun’s rays from day to day and season to season; how the solar tracker would withstand the weather; and most vexingly, designing the mechanics for the complicated movements of the tracker, while ensuring surplus power was generated. Dealing with these contrary demands necessitated continuous proposals and refinement of images of the solar tracker: its structure, mechanics, and its embeddedness in a context. According to Nelson and Stolterman (2003), design communication is best understood as an iterative dialogue about and through images (p. 175). Putting contextual and technical discourses in productive conversation together meant inventing forms and features that could satisfy these various demands. Each image that was discussed, figured, or discovered was an attempt to realize the design problem and open it up to further refinement. In this way, framing as it
occurred in the observed design relied on image-making as a way to constrain various discourses of concern and simultaneously make evident gaps in what was understood or accounted for in the articulation of the design problem.

To start with an example of framing, I reproduce a transcription of Silvio making a pitch for a solar tracker. This transcription and those that follow come from a design meeting where students were explicitly “reframing” the design problem. While reframing is topicalized in this specific meeting, the framing activity represented herein is representative of the students’ design process as a whole. They never stopped producing and debating about images. Every meeting, group members described, drew, and gestured towards internet images that would be used to persuade others on how to design the solar tracker. Because the students were in the reframing stage they had settled a few points about the solar tracker (dual axis, marketed to rural framers of Ontario, to be installed on flat land and not a roof) and were now brainstorming design ideas. The professor had implored them to generate ideas through brainstorming methods she presented in class, but the students found that the current of design conversation, its ongoing “social order,” made it hard to follow the brainstorming guidelines (Matthews, 2009). Instead, they presented their ideas and discussed them openly. Silvio, Nico, and Benny were assigned to sketching duties, everyone else had a different duty delegated by the team leader Bob, but as the meeting went on, it became apparent that each group member had been preoccupied with the design of the solar tracker and came prepared to share their ideas in any way they could. After some discussion of just what part of Southern Ontario they focus on, a lull in the discussion ensued, and Silvio took the opportunity to present his idea. The group sat around a table and Silvio sat up straight, his sketch notebook in front
of him for himself and the group to see. He began with an apology for his artistic ability (every member of the group apologized for not being industrial designers before they commenced sketching or explaining what they had sketched) and then launched into his design:

Slivio- So we all kinda decided that we wanted some kind of um either it was going to be a pole or stand that rotates at the base, at least that's so far what the designs are. Um, my design would be kinda, it'd be a tripod kind of thing (fingers tips of each hand touch to form for a triangular shape) and then in the middle there is a bar across (gestures a bar across in the space where he had formed a triangle) so it's like a triangle, [like a teepee]

Pranav- Yeah]

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10 The transcription conventions are adapted from Wood and Kroger (2000). "[Lines]" designate overlapping talk; "=" latching of utterances; "(.)" noticeable short pause; "(Bolded Brackets)" description of gesture; "[[]]" transcriber’s comment; "((double parentheses))" transcribers description of off camera action; "ro:wing" indicates an elongation of a syllable or sound.
Silvio- [inaudible], And then on the other side there is a bar across it (makes bar motion again) And there's a wheel (makes a circle with fingers of both hands, looking down at sketch book) and the solar panel's attached to one side of it (right hand makes vertical motion up and down) ((suppresses a cough))

Silvio- (Looking down at sketch book) And then underneath that wheel, you could have a little cupped metal piece with treads on it (cups hands open up towards the ceiling, and then uses right fingers to touch off “treads” on the remaining cupped left hand) so you either move this part (starts to move cupped hands to the right)(.) or actually you would have a flat piece (flattens left hand) and you would push that this way (pushes flat piece to the right) and that would actually rotate the wheel (makes hand gesture for wheel, and rotates it to the right) and that would have the solar panel on it (puts right hand flat to the right of approximately where he just had gestured the wheel), um. And that way you wouldn't actually have a motor turning that wheel you'd just get the track moving (hands down underneath the table). Um=

Pranav- =Kinda like a ball and socket joint?

Silvio-Yeah, kinda of. So that's kinda how my idea was.

Silvio first framed his idea with an explicit appeal to the group consensus that the tracker design would be mounted atop a pole. This initial frame was not only grounded in the group consensus from the previous meeting, but was grounded in the various images of solar trackers that were discovered in research on the internet. Thus, the initial move Silvio made was to take up the group’s attention to a particular structure of the shared image in order to frame his idea more persuasively (see Swarts, 2004).

To make the image he had sketched vivid to the group, he described it verbally and visually. He first laid the design notebook in front of him so both he and the group could see to what he referred. Silvio then described and amplified (Wickman, 2013) his idea by sketching it in the space in front of him as he faced the group. In line with Haas & Witte’s (2001) findings on gestures in collaborative work, Silvio’s gestures were “representational tools” used to enlarge the sketch, showing its structure and tracing its dimensions (p, 444). However, Silvio’s gestures were more than tools to represent, they
were the primary representation. His pantomimed construction of the object was the most perceptually salient aspect of his framing. Moreover, he buttressed his description with analogous structures that clarified his sketch for the group: a tripod/triangle support is “like a Teepee.” Pranav’s “yeah” establishes his continued attention and collaborative expectancy. He was visualizing with Silvio, and encouraged his further description.

Silvio’s description also touched on how his design would move and used gestures to ‘rotate’ the wheel mechanism. By showing the movement of the mechanism through gesture, Silvio compensated for the motionless sketch he had in front of him. The sketch, no matter how detailed, cannot capture the movement of the solar tracker wheel like a gesture that can display and mimic its trajectory. Gesture afforded motion gave the image Silvio constructed a vivacity that even sketching could not duplicate. This is an important feature of gesture that came up again and again in the student’s framing activities. Gestures for motion, such as the motion of gears, the movement of the solar panels, or the earth’s track across the sun, were ubiquitous throughout designing. Gestures animated words, sketches, internet images, and even CAD drawings, to bring the action of proposed design ideas into contact with technical and contextual concerns (see Becvar, Hollan, & Hutchins, 2005).

Collaboration is fundamental to framing, but it manifests in a particular form. Silvio’s sketch and description were vivid to the point that Pranav offered an analogy of “like a ball and socket joint” to demonstrate to Silvio that he was attending to his description and that identified with it to the degree that he offered an analogy to a mechanism that was common knowledge for the group. Pranav demonstrates Burke’s collaborate expectancy by using Silvio’s description to invent his own frame for
conceptualizing the mechanism for the solar tracker. Later, after several turns in the
corner, Pranav will deliver his own design idea that will use the ball and socket
joint analogy and Silvio’s design as a frame for attending to his idea. The links between
the two frames provide insight into how image-making works in design teams. The vivid
image is persuasive to the degree that it is built upon with new frames that either select
aspects of a prior image to construct another image or integrates a prior image into a
more extensive elaboration of the design.

The performative and rhetorical power of design talk is well-attested in the
literature. Andy Dong draws on queer revisions of speech act theory to make the case that
“language [be] seen as not only the message carrier but implicated directly in producing
the carried” of design (p. 16). For Dong, design talk constitutes and enacts the design; it
is the talk of designers that shapes and evaluates ideas, brings contexts into being, and
composes the texts of design. Geisler and Lewis (2007) note that talk, especially
narrative, fills out the social situation that designers design for: they relate how an
engineer’s recollection and narration of a person he knew who was wheelchair bound
evoked a “concrete image” of a device that would inform the design of a mobility
product for children suffering cerebral palsy (p. 321). Lloyd and Busby’s (2001) analysis
of engineering talk reveals engineer’s preference for using language to construct “verbal
models” of phenomena under group consideration (p. 77). The ability to create vivid
verbal models allowed the engineers to quickly assess and debate the merits of a frame.
Peter Medway (1996; Medway & Clark 2003) sees talk as one semiotic mode among
many that construct the virtual object that designers refer to in the course of their
designing. The virtual object is more or less defined and concrete, depending on how
textually materialized it is and how many relevant designers share the materializations as reference for it. In Medway and Clark (2003), the charting of the design through an architect’s office leads Medway to characterize the design representation as a “palimpsest;” the overlaying of ideas, talk, sketches, considerations, and regulations forming a thick cluster of meanings which the design stands as an embodiment (p. 271).

For all of the above researchers, design talk is constituting of the design itself, the object and the process. Additionally, each researcher (with the exception of Dong [2007, see p. 19]), sees talk as producing, maintaining, and contesting images of the design object. It is this aspect of framing that resonates with the activity of student designers. In the early conceptual stages on through the night before their presentation was due, students strived to make vivid design images for each other and induce each other to identify with those images. I use “identify” in reference to Kenneth Burke’s (1969) well-known concept of identification, the act of seeing or inducing one to see another’s interests, values, identity, philosophy, politics, etc. as akin to one’s own. While that definition of identification certainly pervaded in the group’s framing activities, it is Burke’s elaboration of identification with his notion of “collaborative expectancy” that begins to describe the group’s act of image making (Burke, 1969, p.58). For Burke it was not only the content of the message or the meaning of the symbol, but additionally, and maybe inexorably, the form of its transmission that established identification between speaker and audience. The hearer, in order to follow what is said has to assent to the formal composition of how something is said. Verbal models, narrative descriptions, layers of the design palimpsest, all have formal features that afford quick assent and collaboration. I conflate here not only the form of an argument or a figure, but the form
of an image, seeing in both sense of “form” a persuasive element that describes the
framing activities of the group (see Van Eck, 2007, Introduction). In other words, in
making images/ deploying figures of argument, either verbally, or as I will show below,
gesturally, graphically, or digitally, students sought to have their peers identify with their
design idea by inducing collaboration. A student’s rhetorical display succeeded to the
point that it could be vivid and fitting enough that the rest of the group took it up in some
way, that it could be attended to in the same way. The displays I focus on here are figures
of hypotyposis, the rhetorical figure of argument that persuades by bringing an imagined
scene or object before the eyes of a viewer (Fahnestock, 2011, p. 335). In hypotyposis,
the form of an argument and form as image are united in one figure.

**Hypotyposis in Framing:**

I use the specific term hypotyposis for 1) the simple serendipitous reason that its
root form means to sketch and sketching is associated with design; 2), the term’s
definition as a-bringing-forth points captures the continuous aspect of framing as active
and ongoing; 3) hypotyposis describes the texture of framing: the putting forth an image,
the co-construction of the image by the participants, the grounding of the image in culture
competence and experience (described below); and 4) finally, the figure focuses not on
making an object, but instead in attending to things in a particular way together. Scholars
have found that hypotyposis is one of a group of terms in ancient Greek and Latin to
describe the process or act of bringing before the eyes a scene or object, making the
absent present (Eco, 2004; Fahnestock, 2011; Plett, 2012; Webb, 2009). The figure of
hypotyposis has no canonical form, unlike (say) chiasmus or asyndeton, although for
ancient and contemporary rhetoricians alike hypotyposis has several distinct qualities.
Aristotle states in the third book of the *Rhetoric* that in order to bring a thing before the eyes of the audience, that thing must be described with energeia that is motion, vivacity, and energy (III.11.1-4). Umberto Eco in a survey essay of the figure, finds that hypotyposis first of all denotes; that it requires detail, but not so much detail that the hearer cannot imagine for herself what is being made present; that it often takes the form of lists; that it accumulates events of a scene; and finally that it appeals to the listener’s cognitive and embodied experience as way to make the listener intensely feel what is described. (Eco, 2004, p. 188-196). The effectiveness of hypotyposis to make the absent present by forming a connection from the speaker’s imagination to the listener’s imagination is also predicated on what Ruth Webb (2009) describes as “cultural competence” (Webb, 2009, p. 124-125). Cultural competence refers to a background of experience and knowledge that speaker and audience must share in order for the formation and transmission of an image. An audience must, for instance, be familiar enough with Tiberius Gracchus and his circumstances to accurately imagine the scene of his murder vividly recounted in the *Rhetorica ad Herrienum* (IV. 5. 68-69). As Webb points out, to find Susan Smith’s fabricated account of the abduction and murder of her children by a black man persuasive, listeners must have knowledge of the pertinent racist stereotypes and horror stories upon which she drew (Webb, 2009, p. 125). I see Webb’s cultural competence and Eco’s stipulation that hypotyposis as depending on the listener’s cognitive and embodied experience as complementary. Webb’s focus on a kind of cultural inventory of reference and Eco’s notice of the experiential qualities at play in the force of hypotyposis present a complete picture of the resources audiences use to make an object present.
Both ancient and modern rhetoricians posit hypotyposis as a way for a speaker to induce a listener to identify with her account by collaboratively imagining what the speaker vividly recounts. Though I have focused on the classic rhetorical situation of speaker/writer communicating to an audience, hypotyposis is a figure deployed by visual artists as well (van Eck, 2007; Farrall, 2006; Plett, 2012). For instance, Heinrich Plett (2012) explains how perspective in painting is a technique not for mimesis, but instead a mediation between the imaginations of the painter and viewer: “the artist of a visual creation must, in a sense, be a *euphantasiotos* [good at imagining] in order to adequately realize the perspective of an art work from the beholder’s point of view. And the recipient must also be a *euphantasiotos* in order to gain an adequate perception of the visual art object” (Plett, 2012, p. 122). Visual arts rely on similar requirements for successful hypotyposis as the verbal arts do; namely, that both speaker and listener must be imaginatively inclined. And being imaginatively inclined means possessing and displaying cultural competence and the power to vividly make the absent present.

A discussion of hypotyposis in design or engineering has not been taken up in the research literature by either TPC or design research. This gap is interesting because both disciplines rely heavily on the visual. As noted above, designers go to create lengths to frame a consensus image that can ground and further their inventional work. Eugene Ferguson (1994) proposes that engineering knowledge and education is primarily facilitated by what he designates as the mind’s eye, “the locus of our images of remembered reality and imagined contrivance” (p. 42.) Engineers, Ferguson posits, rely on nonverbal communication and education; they think and talk in sketches and learn best by doing, with first-hand experience of mechanisms and processes. Kathryn
Henderson’s (1991, 1999) ethnographies in engineering firms found that engineers would stop meetings to fetch drawings to supplement ideas and/or immediately go to a whiteboard or grab a piece of paper to start sketching a proposal or problem. Visuality, image making, and persuasion are constitutive of engineering design and its framing activity.

The role of imagination is a less settled point, however (for an example of the debate see Pylyshyn, 2003a, 2003b; Kosslyn, Ganis, and Thompson, 2003). Whether we represent images in our brains as we perceive is a complex and thorny debate at the heart of many disagreements in the cognitive sciences, philosophy, and social sciences. However, in rhetoric that we construct images in the mind and that rhetoric can create or induce others to create mental images has been taken for granted by most theorists. Debra Hawhee goes so far as to make the connection between the ancient psychology underlying the figure of phantasia in Aristotle and other sources with contemporary cognitive theories of mental imagery (Hawhee, 2011). In empirical human sciences, researchers and theorists are less comfortable with the idea. When studying engineering, however, social scientists cannot help but contend with its imaginative aspect. For instance, Kathryn Henderson, (1999) a sociologist and adherent of the decidedly non-cognitive Actor Network Theory, concludes her monograph on visual communication in engineering by acknowledging the place of mental imagery in the practices of engineering. However, Henderson notes that visual communication like sketching is not simply a vehicle for mental images; rather it is the interaction between the mental image and the act of sketching that fully accounts for how images are produced and communicated. Keith Murphy (2004, 2005) goes even further, while not suggesting that
the contemplative mental image construction of imagination does not have a place in design, he does show how imagination in an architects’ office is the accomplishment of textual, embodied, and material practices that create publicly available images for visual scrutiny within interaction. An example of what he means would be someone using their hand as a hypothetical wall on a set of drawings to (say) show what a room would look like divided; the image now seen is imaginatively changed, but not in a primarily mental way. It is enacted by the gesture on the representation, the image is therefore seen as much as imagined. This point, of course, settles little to nothing about the mental imagery debate. It does, however, allow researchers interested in the imaginative acts of people in real life interaction to not have to resort to positing the operations going inside participants’ heads, which they cannot see. Instead, researchers can take the sequences of interactions as indicative of what is or is not actually imagined. When discussing the image making and imagination of engineering students, I adopt Murphy’s (2004, 2005) perspective (see also Alač & Hutchins, 2004). I stress, however, that it is not quite correct to say that designing is making a series of images, up until a satisfactory image can be called the “design.” Rather, hypotyposis is an attending to possibilities through image-making.

Hypotyposis in design framing is collaborative in a way that many theoretical approaches to the figure miss. While hypotyposis is acknowledged to need an imaginatively inclined audience to take up the image, in design this uptake is part of a process of collaboration that generates still more images in order to ground communal understanding and further collaboration. Framing, then, is the activity of producing and
using images to bound the attention of designers to a particular design effort at a point in time.

The next example from Sedat’s design idea does just that. Nico had found an image of a worm gear on the internet that was animated as a gif. Discussion arose of how a worm gear might be useful in accomplishing the two movements necessary for a dual axis tracker, the diurnal and the seasonal. Additionally at issue is how the gears will be protected from the Ontario winter and ensure that the power taken to move the motor does not drain too much energy from what is stored for the customer to use. Sedat asks Nico to turn his laptop computer towards him as he folded his own down and addressed the group seated round the table:

Sedat: Maybe instead of a cable that would be exposed we have that in a gear box (points to Nico’s open computer displaying an image of a worm gear)
Pranav- (Looking at Sedat) Yeah [inaudible]

Sedat- (Puts one hand above the other to make a box) And then we have an extension (right hand cupped moving up and down as if gripping the length of a pole) (. ) out of it (points to worm gear) that pushes it out (right hand moves up in pushing motion) and then the same vertical will be (. )(he puts hands up, palms facing each other about 20 inches apart) and then you have two supports and the, like, you take one motor (. )then you have two on each end (hands turn downward as if preparing to play a chest-high piano, then hands turn over and fingers are made vertical again, palms facing upward) and then you'll be pushing it [inaudible]=(right hand moves up, left hand moves down simultaneously)

Steven- =See also with that, like you could generate-so if you turn ( puts hands up to mimic Sedat's spacing) so if you turn one motor on and turn the other one off so it pushes one up and pushes the other down (the left hand goes up and the right hand goes down, creating a mirror image of what Sedat just performed) you could possibly turn the other motor (points to Sedat) and maybe generate [inaudible] 'cause then you'd be (right hand goes up , index finger gets pointed out, finger drops slowly) (.3)I don’t know (makes a beat gesture), I don’t know if that would actually work with that but (pauses a beat, then resumes the pointing gesture that drops slowly)(1.0) but (drops iconic gesture, goes back to beat gesture) but it would be saving energy to turn one off and push the other one up.

Pranav- I know what you mean, like a cable car system=

Steven- =Yeah

The moment of framing here is remarkably multimodal, as a .gif, gestures, and talk bound attention to emergent mechanical concerns resolved through image-making.

Sedat’s deictic gesture to Nico’s worm gear .gif is what Oakley (2009) terms a semiotic integration, a distributed cognitive process of making meaning through and with artifacts and imagination in a socio-technical situation (p. 103; see also Hutchins, 2005). Sedat first made the .gif publically available by his pointing gesture and words, and distributed the group’s attention between the computer screen and his description. He then integrated the worm gear into his own framing for the design by gesturing how the gear would be encased within the hypothetical image of the solar tracker. Through
pointing to the screen and explicitly describing structures that use it (“we have an
extension out of it that pushes it out’), Sedat focused the group’s attention onto a new
virtual object, an integrated one of Sedat’s words, gestures, and Nico’s computer
screen. The computer screen anchored the integration of the worm gear .gif with
Sedat’s gestures for motion and structure and become components of one image.
Sedat’s integration was not only creative; it was opportune. The gear and motor had
been the most difficult to conceptualize and sketch for the group at this point (and it
continued to be an issue). Sedat saw that an image constantly displaying its motion as a
.gif afforded a vivid representation that he could exploit to offer his perspective on the
design of the solar tracker. The perpetual rotation of the worm gear .gif captured one
element of motion, allowing the group to focus on constructing and animating other
mechanisms.

Though Sedat seems the orchestrator of his demonstration, the situated
environment he and the group are embedded within constituted the kairos he seized.
The group is already in a participation framework, “a mutual align-ment of the
participants’ bodies” that grounds the talk in the immediate material surround to which
all are attending (Goodwin, 2007). Sedat uses the alignment of bodies and artifacts to
describe an image for the solar tracker that takes the situation as its component parts.
However, it is through his gesture and talk that he selects the elements for the image he
is making. The creative aspect of his hypotyposis sprung from the way he attended to
the situation at hand.

The worm gear .gif is a resource for Sedat’s rhetorical performance. Through
that performance, the worm gear is transformed from an apodeictic display of
mechanics taken from a Wikipedia entry to a rhetorical display “showing forth” an
argument for a new design (see Fountain, 2014; Prelli, 2006, p.8). The representation of
the worm gear bears a new relation and understanding for the group by being a resource
in a semiotic “field of interaction” where meaning is produced and negotiated through
situated movement and talk (Alač, 2011, p.24). The strip of talk also makes clear that
Sedat’s rhetorical performance is dialogic, as Steven immediately aides Sedat by
mimicking his movements and pushing the description farther to include another
technical concern, that of energy efficiency. Hypotyposis opens up images for
reinterpretation and elaboration in addition to constructing them. Eco (2004) illustrates
this point clearly when he cites an absurdly dense and detailed passage of a quay from
the New Novelist Alain Robbe-Grillet (Eco, 2004, p. 189). Because of the intentional
overabundance of description, the reader cannot even imagine what is being described.
The welter of detail overrides the capacity to imagine and the words cease to paint a
picture, becoming only words. Hypotyposis needs to be detailed enough to allow for
imaginative collaboration, but not so detailed that there remains no image to construct.
It is likely that if any member of the student group brought into the conceptual design
meeting CAD drawings of the full design, an exploded view of the subassembly, and
perspectival drawings of all the parts, collaboration as both the course and the group
intended it would be frustrated. The act of bringing forth a design is what the design
group is for; given a full design, the group can analyze and deliberate on how well it
meets customer requirements, but the creative part of design is lost or at least severely
hampered.

Finally before moving on to a last example and concluding, it’s important to
note Pranav’s analogy. His “like a cable car” grounds both Sedat’s image and Steven’s
expansion of that image into a new frame. The frame is a selection of likenesses of the
two hypotyposes embodied in the image of the cable car, or more specifically, the mechanical movement of the cable car. The resultant framing bounds the phenomena under a new heading (so to speak) and further discussion will either take up the frame or discount it based on new criteria. In this way, analogies and other instances of abductive reasoning (Murphy, Ivarsson, & Lymer, 2012) also form bridges between frames, either shifting or augmenting them. Analogies work to fill out the presence of the image by drawing on well-known and well-understood mechanics, and they part of the cultural competence and experience students draw on.

In the final strip of framing, sketching plays a prominent part. Sketching in design has received an immense amount of attention from design researchers and cognitive scientists. (See van der Lugt, 2005 for an overview). Early treatments focused on the individual designer using sketches to work out problems (Goldschmidt, 1991; Schön, 1983), while others saw sketching as an example of the interplay between mental representations and material tools (Fish & Scrivener, 1990; Tversky & Suwa, 2009). Other researchers interested in the social nature of design examined sketches as mediators of interaction (Bucciarelli, 1994; Ferguson, 1994; Henderson, 1991, 1999; Tang, 1990). In the design meetings, sketches were either brought in from home, or they were composed on the spot. In either case, the function of sketches was to frame design ideas. A clear example came as Bob, the team leader, sought to synthesize ideas discussed in the group. The discussion remained focused on how to turn a solar tracker and the kind of motion it should take. He literally called for the group’s attention and then started to sketch and narrate what he sketched:
Bob- What if we do (. ) imagine- a pole coming out (starts to draws pole at right angle from previously sketched shaft) pole there, pole there (draws poles at two points on the paper) and the pole came out like that too (draws a pole that extends out to the viewer). Um, chains go [indistinct] (draws line connecting to the poles) (1.0) And this is rotated (makes semi-circle underneath shaft) and this is dragged along like this (traces chain).

((Silence for a moment. A couple of muffled questions are asked off screen))

Steven- Are they gonna be like a triangle kind of shape, (makes a triangle with his hands) So like one's over here and another's over here (he points to two points on the triangles and moves his hands down to frame the table top in with fingers shaping a triangle in front of him) and coming out like 120 degrees?

Bob- Imagine, imagine a pirate ship.

Pranav- Ok

Bob- So you know they- the workers pushing the thing around the things (makes a sweeping oar motion with both arms, two times)?

Pranav- Right
Bob- That’s what I am imagining (makes circle motion with one hand, as if he's stirring something)

Steven- Oh, ok

The sketch plays a role similar to that of gesture, computer images, and talk. Bob’s sketch acts as a conscription device, a visually oriented artifact that enlists the participation of the other group members (Henderson, 1991, p. 452). He doesn’t treat his sketch as speaking for itself, nor does he assume that sketches conscript all on their own; rather he enlists the group in a particular kind of activity, to “imagine” what he sketches as he sketches it and describes it. As noted above, Bob’s sketching is a synthesizing act trying to reframe the discussions of the meeting, to give form to the competing concerns. His instruction to imagine is also a call for the floor to speak and specifies the way he hopes his team members will attend, that is, quietly and with concentration.

He sketched the pole supports for the rotation of the solar panel upon a previously sketched tracker. The sketch pad was overlaid with prior sketches, the traces of other frames and frame shifts. He described how three poles extending perpendicular to the main shaft could be connected by chains to rotate the tracker to capture the sun’s rays. He sketched the direction of the motion as well. After a moment, several questions from the group came at once, but it is Steven who was sitting next to Bob who gets the uncontested floor to speak. He framed the sketched structure like a triangle, which he flattens against the table to foreground the shape of his fingers. Bob saw that his sketch, while conscripting the group’s creative efforts, had not communicated very well; it had failed to make his intended image present. He then pantomimed a rowing motion of a galley slave at the oars beneath a pirate ship. The pirate ship itself was not intended to structure the image of the solar tracker, rather it contextualizes the rotation Bob’s sketch
attempts to bring forth. It is the motion of the galley slave’s rowing that supplements and animates the sketch. Bob’s sketched image is brought into focus and made vivid by iconic gestures from Steven and Bob himself. The new framing is anchored in Bob’s sketch, Steven’s discounted triangle. Bob’s rowing motion, and talk of the group. Once this assemblage, a product of multimodal interaction, has coalesced in a frame that has bound the attention of the group, Steven responded with an utterance of understanding.

Sketching, then, while being of great importance to engineering, as Kathryn Henderson (1991, 1999) and Eugene Ferguson (1994) have convincingly argued, is just one element in the image making activity of engineering designers. Talk, gesture, and internet searches emerging in the course of interaction invent new frames by bringing forth and making present images of the design object, or parts or contexts of the design object. Sketches play the role of interactive floors where decisions, disagreements, hypotheses, and consensuses about the design are made (Henderson, 1991; Suchman, 1990), and also afford inscriptions of the image. But, they are made present to the group, imbued with clarity and counted as evidence of joint attention through the multimodal interaction of the group. Images are accounted as images of something through group attending, and not solely through fidelity or likeness to a mental representation or referent. In the students’ design process, framing was accomplished through hypotyposis. Image-making conscripted attention to an idea, perspective, or value by delineating phenomena and inviting collaboration. Framing, as the data reveal, is a process of directing attention, of making available to scrutiny ways (in this case, ways were images) of figuring technical and contextual problems. In Dorst’s (2006) terms, framing is “a redefinition of the problematic situation in order to create a solution” (p.14). Each image
is a way of defining a problem, giving it shape and presence. But the image does not fully
represent or encompass the contradicting discourses of the design situation. Instead, the
image invites more discourse, brings more concerns to the fore, provides opportunities
for invention and further entangles designing in technical and contextual questions that in
turn are taken up in still more framings. The design process did not always move
seamlessly on, each configuration leading to a more perfect balance of design constraints.
There were many, many more dead ends, unworkable ideas, and miscalculations than
there were viable designs. But the students made images to lead them to a design
satisfying as many of the design requirements as possible.

Techniques of Presence:

The analysis of the student group’s framing activity revealed several things.
Students’ framing was a type of rhetorical figure called hypotyposis, a bringing forth of
an image. This image was never completely detailed, but was brought into presence to
such a degree that the group could take it up through further interaction. An example of
a frame not taken up in further interaction was Benny’s sketch for the tracker. Benny
delivered his idea to the group by pointing to the sketch he had brought in with his
pencil and described how it fit together. After he had finished, he immediately went on
to describe the tardy Nico’s sketch idea, which he also had brought with him. Benny’s
presentation, compared to the others, was terse, unanimated, and uninviting of
collaboration, and his design ideas were not discussed. It would be better to say that
Benny did not employ hypotyposis in his description. Of course, the design itself could
have been poor (not trained in mechanical engineering and not participating in the
project, I am not in a position to assess it), and that is why Benny and the group passed
over his design. But I argue his delivery affected the reception of his design as well.
The fact that he did not expend effort on making his image for the solar tracker vivid prevented uptake of his frame.

It is this kind of result that many of Professor Connolly’s brainstorming techniques were meant to combat. She stressed that ideas should be heard and built on rather than received in silence or discounted. She repeated often in lectures that brainstorming was like “improv comedy. You never say ‘no.’ You always say yes to the idea and how can we do it. The selection comes later on.” This points to the consequences of students reconfiguring or ignoring the sanctioned strategies of attention, such as brainstorming techniques, for their own use. By proceeding according to how they wanted to develop ideas, some ideas were not heard, and some students did not get to develop or practice necessary rhetorical skills.

Another finding from the data suggests framing is multimodal and does not privilege one mode over another. Framing may be achieved through sketching, talking, gesturing, or through various technological means. However, gesture was the preferred mode to animate sketches, to demonstrate movement of parts, movement of the earth around the sun, and the turning of the motors. These findings broaden the perspective on gesture and embodiment in TPC (Fountain, 2014; Haas & Witte, 2001; Prior, 2010; Sauer, 1998; Wolf, 2005) by revealing how gesture’s capacity to create motion provides a dimension of vivacity to scientific and technical descriptions, and strengthening the link to similar work in discourse studies, cognitive science, and science and technology studies (STS) that looks at the way meaning is made in socio-technical environments (Alač, 2011; Becvar, Hollan, & Hutchins, 2005; Oakley, 2009). Still, it is important in researching persuasion in such complex environments as those of group design that all
the modalities of rhetoric be accounted for because the force of presentations is rarely if ever the result of only one modality (Alač & Hutchins, 2004, p. 638).

Frames were spatio- temporally stabilized by being embedded in the participation framework of the group meeting. They were elaborated through abductive reasoning, most notably analogy. Murphy, Ivarsson, & Lymer (2012) gloss abductive reasoning as: “the observation of a set of circumstances in one context, followed by a reflection on or recognition of other phenomena whose features, sometimes abstract, sometimes concrete, plausibly match those of the case under consideration” (p. 534-535). The analogies of the ball and socket, cable car, teepee and the rowing motion sprung from the recognition by group members of the presented image’s mechanics matching common, known, and well understood examples of objects with similar mechanics. Such reasoning imbues images with vivacity, making them more present to the group by being grounded in cultural competence and experience, to recall Webb (2009) and Eco (2004).

Finally, hypotyposis in engineering design may be different in a crucial respect from creating a vivid account in a courtroom, painting a beautiful picture, modeling a protein, graphing market data, or other kinds of bringing before the eyes or making the invisible visible. The image-making of engineering design often requires a mutual elaboration of a hypothetical object and context. The students’ solar tracker has no features, form, or purpose without attending to where it will be sold, to whom it will be marketed, how it will work where it is to be sold, its product life cycle, just to name a few concerns. These concerns directly impact material selection, mechanics, the power source, manufacture, and maintenance. The image of the solar tracker, then, is not simply a conjuring up and delivery of an object or event that is vivid and detailed; it is
not a process of revelation as in scientific enterprises. Rather, the image emerges from the framing of contextual and technical concerns. In fact, calling it an image occludes the texture of the making, which is less a composing or constructing and more of a tying together of competing and contrary concerns. *The image is an index of the contextual and technical, but not like a picture, which is beheld. Rather, images are visualizing actions to direct attention to addressing technical and contextual concerns in a particular configuration.*

Further research is needed to understand the subtle ways aesthetic or stylistic features are incorporated into design. The rhetorical process analyzed above provides a window into how images are collaboratively invented in conversation with the situation in order to frame design concerns. What also needs to be understood is the way designers incorporate surplus meaning or effects into their designs. Designs are not only responses to contextual and technical requirements; they are constructed with an eye towards the personal expression of the designers or corporation, and a theory of how clients will want to feel or appear using a product, system, or process. In other words, there are opportunities for rhetorical theory to dig deeper into the processes of technological production and reveal the ways artifacts are the way they are and are used the way they are used (see Lynch & Kinsella, 2013 for a programmatic statement).

As part of this study, the analysis of student’s framing methods provides a moment of attunement, where students designed according to the dynamic social order of their group. They were not able to align their own idea generation with the strategies from the course. They were not necessarily derelict in this action, because their activity actually recalled similar sequences of designing from both novices and experts in diverse disciplines, as noted in the citations above. Framing happens in the way described in this
chapter, perhaps more than according to the brainstorming strategies put forth by EMAE 260. The misalignment between the attention from the course and the attunement within the group, however, resulted in a failure to give everyone’s ideas equal treatment. Thus, not everyone was able to practice the necessary skill of moving students to develop a design idea through image making.
Chapter 4: Judging for Themselves: How Students Display Engineering Judgment

In the previous chapter, I explicated how students used the rhetorical figure of hypotyposis to construct images to direct attention to configurations of contextual and technical requirements of their design project. In order to make these images present, students used talk, gesture, sketching, and internet searches to invent and elaborate ideas. Embodied and multimodal means were employed to both put forth images and gather input and reflection from the group in order to further the goals of the design process.

Over the course of the semester, the process of invention grew organically from the dynamics of the group, and not according to the concept generation practices set forth by EMAE 260. It is here in group work where students start to develop first-hand, practical knowledge of engineering design distinct from its representation in lectures and textbooks. In group work is forged the experience with tying images to requirements and requirements to images. But designing an object is one experience students are supposed to have; another is the experience of practicing their nascent engineering judgment.

Engineering judgment is an unruly concept, but engineers seem to mean by it the ability to perceive how an engineering matter should be carried out properly. In this chapter, I examine just how student engineers make judgments as part of the process of design, and I do so in order to offer some definition to a rather vague and amorphous concept, namely engineering judgment. An ethnomethodological -inspired analysis of the data suggests engineering judgment is a rhetorical activity using displays, gestures, and talk to orient participants’ attention to common sense. Analysis further suggests just how engineering judgment is a rhetorical practice by focusing on the situated dynamics of the group
interaction. The integral role of rhetorical displays and gestures in engineering judgment speaks to recent work in engineering education focusing on the importance of representations (Johri, Roth, & Olds, 2013; Juhl & Lindegaard, 2013; Roth, 2014). The findings are elaborated by connection with postphenomenological understandings of the role of the body in scientific and technical work. I suggest judgment may be an important mediator in body and technology connections and extension as articulated by postphenomenology\textsuperscript{11} theorists in science and technology studies (STS) (Carusi and Hoel, 2014; Carusi and Hoel, 2015; Verbeek, 2005).

The chapter will continue to provide evidence suggesting how students learn to attend to engineering through a practical and rhetorical engagement with designing, and how this engagement is in tension with the formal education of attention in the classroom.

**Understanding Engineering Judgment:**

Engineering judgment is a core competency for engineering practice. Philosophers, educators, practitioners, and historians agree that engineering judgment is necessary for ethical, sophisticated, and professional engineering practice (Davis, 2012; Ferguson, 1994; Holt, 1997; Petroski, 1993; Vincenti, 1990). While scientific and mathematical knowledge undergirds engineering practice, and communication skills facilitate it, engineering judgment governs the appropriate and ethical application of

\textsuperscript{11} Postphenomenology is Ihde’s (2009) term for a phenomenology that has moved beyond subject/object terminology to investigate interactions and configurations between bodies, technology, and environments. Postphenomenology dovetails with work in STS (Carusi & Hoel, 2014) and design theory (Folkmann, 2013; Verbeek, 2005), and is particularly helpful in understanding the body’s work with tools both symbolic and material in pursuing technological and scientific goals. I bring a few of its insights to bear on the rhetorical practice of engineering judgment.

> Necessary as the analytical tools of science and mathematics most certainly are, more important is the development in student and neophyte engineers of sound judgment and an intuitive sense of fitness and adequacy. No matter how vigorously a “science” of design may be pushed, the successful design of real things in a contingent world will always be based more on art than on science. Unquantifiable judgments and choices are the elements that determine the way a design comes together. Engineering design is simply that kind of process. It always has been; it always will be. (pp. 193-194)

For Ferguson, the relationship between engineering judgment and science and mathematics is one of deployment and application. This deployment and application is “more important” than the learning of “analytic tools” for understanding the “nature of the education that an engineer requires.” For Ferguson, engineering judgment is not only a fundamental competency for engineering, it is of the utmost importance for producing a professional engineer. More forcefully, and in agreement with Davis (2012), he sees design itself as the primary arena for engineering judgment (p, 806).

While the priority of judgment over analytic tools is debatable, engineering education in the United States and elsewhere has put engineering judgment on equal footing with analytic tools as a necessary component for an engineer’s education. ABET criteria do not use the word “judgment”, but Criteria 5 (b) of the curriculum requirements does define engineering design as “a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert
resources optimally to meet [client’s] stated needs.” (ABET, 2016). As a decision-making process, engineering design includes the act of judgment (Gorman, 2002). Decisions are arrived at through judgment; it is judgment that recognizes when a decision is to be made and the reason for making such and such a decision (Davis, 2012, p. 779). Judgment is prior to decision-making and is itself a generation or selection of reasons for arriving at a decision.

Engineering judgment has no formula, algorithm, or heuristic, so educators put students in situations that call for the practice of engineering judgment, hence the proliferation of design courses in undergraduate engineering programs in the last two decades that seek to emulate the kinds of constraints and requirements of professional engineering. It is in these classes where the development and practice of engineering judgment is most likely (Davis, 2012), owing to the necessity of making decisions on how to satisfy contrary demands (Dorst, 2006). How judgment happens, though, or how best to foster it is less understood in the engineering education literature and almost entirely absent from technical communication.

Additionally, in delineating the importance and implementation of judgment, there is left unanswered the question of just what engineering judgment is. In a survey of the literature, engineering judgment is understood in different ways and with emphasis on different aspects. Davis (2012) thoroughly evaluates the slipperiness of engineering judgment and the way it cannot be said to equate to decision-making, phronesis, discretion, discernment, or common sense, but is related to all of them.12 He concludes

12 As the chapter unfolds, one might wonder why phronesis is put aside when seeking an understanding of engineering judgment. I preempt speculation by noting, for Davis (2012), who follows Aristotle, phronesis is a virtue of one who “has a disposition to act that takes general and particular knowledge into account in appropriate ways (ways not necessarily predictable in advance)” (p. 803). Davis makes clear that phronesis
without a definition of engineering judgment—as he is unable to find one satisfactory—but does discover two prominent qualities, namely judgment creates alternative courses of action and judgment is reasonable rather than rational. For Davis, engineering judgment is a creative act generated under constraints, and it proceeds not from abstract or general formulae, but from practical engagement.

Case studies of professional judgment make experience a primary component of judgment, providing the practitioner with the ability to recognize mistakes, foresee problems, and economize attention (Petroski, 1993; Vincenti 1990). Case studies show how similar problems were handled or were not handled in similar circumstances, thus equipping the engineer with a body of vicarious experience of how to avoid engineering mistakes. The earlier quote from Ferguson (1994) suggests that deployment and application of that body of experience are two components of judgment, a point with which Vincenti (1990) concurs. Holt (1997) makes judgment a skill of appreciation, a perceptive ability to see and fit an idea to a purpose. Holt also echoes Ferguson’s emphasis on “non-verbal thinking” in engineering judgment, suggesting judgment means the ability to visualize reasons for making decisions (p. 114-115). Taken together, engineering judgment is described as a distinct visual and mental capacity to artfully and reasonably deploy and apply lessons from the past and technical knowledge to fit emergent situations.

is a global term, meaning it is not circumscribed by a profession. In other words there is no engineering or medical phronesis, because the person who had good judgment and practice in a profession would be good at their job, but might not have the character to always practice good judgment no matter the situation. The mark of one who has phronesis practices good judgment and decision making in life generally. Moreover, judgment is a component of phronesis. It does not make sense to consider them equal. Good judgment is necessary for phronesis, but someone is not a phronimos who only has good judgment in one particular area of knowledge. See a thorough discussion in Dunne (1993) for a conclusion in agreement with Davis.
Visualization, appropriateness, practicality, and reasoning are attributes associated with a rhetorical understanding of making judgments and persuading others of the aptness of judgments. For Aristotle, rhetoric was the art of the orator persuading people in civic deliberations, judicial proceedings, and praising virtue and blaming vice. Rhetoric was concerned with disposing an audience to make a judgment through appeals to reasoning, character and virtue, and the emotions (1337a1-8). Rhetoric, as the discovery of the available means of persuasion in a given situation, seeks to understand what is an appropriate action for a particular time, place, people, or task (1355b27-8). As such, it has much in common with understandings of engineering judgment that focus on how and when to apply engineering reasoning for developing a specific kind of deliverable for a client. Moreover, the rhetorical approach to judgment aligns with a conception of judgment as a practical engagement. Leff (1999), in evaluating rhetoric’s subject matter and office, offered a conception of rhetoric as rhetorical judgment, a process of uniting argument and style to address practical matters for particular occasions, a conception which is related to the ancient principle of decorum (61-62). He designates decorum as that which “allows us to comprehend a situation as a whole, to locate its meaning in a context, and to translate this understanding into a discursive form that becomes an incentive to action” (62). For Leff, judgment necessarily entails the ability to perceive the stakes of a problem or situation and the concomitant ability to transform that understanding into a discursive form to induce action in others. These discursive forms are not predetermined but depend on the situation.

However, a hallmark of a rhetorical and engineering understanding of judgment is visualization. In an article discussing imagination and judgment, Kennerly (2010)
declares at the outset that, “[r]hetoric’s work often consists of giving presence to the
unseeable – something not yet or never capable of being seen—something visible but
ignored. A demonstrated need for matters past, passing, or to come, gives impetus to
bring the absent or unapparent into view” (269, emphasis in original). By presence,
Kennerly draws on classical understandings of the rhetor’s ability to verbally compose
pictures, to vividly narrate scenes or events for an audience, and put in audiences’ minds
a persuasive account of the way a thing appeared or transpired. The previous chapter’s
discussion of hypotyposis describes a related rhetorical ability, however Kennerly talks
specifically of phantasia, which differs from hypotyposis in the former’s emphasis on
transporting the hearer across space, time, and context through images rather than then
the making of images (in the latter) to solicit collaboration and co-construction.
Kennerly’s analysis, though, effectively demonstrates rhetoric’s use of visualization for
preparing good judgments to be made.

Visualization practices are not only helpful for inducing good judgment in others,
but also preparatory for a practitioner to develop good judgment herself. Fountain (2014)
makes this point in discussing medical students learning the affordances of visual
displays and developing the necessary bodily skills to render anatomical bodies
intelligible before they can exercise and experience clinical judgment (98-99).
Specifically, Fountain notes the role of multimodal displays and embodied processes of
identifying anatomical structures through skillful revealing of the inner anatomy of
cadavers. Fountain augments a view advanced by Prentice (2013) focusing on medical
residents’ development clinical judgment through experience and embodied observation
of case after case of medical subjects by discussing the affordances of technologies,
visualizations, and tools that offer students opportunities for action in the gross anatomy lab (Fountain, 2014, 60-63). Affordance, as it is used here, is a concept borrowed from ecological psychology and designates the opportunities or uses objects in an environment offer. A chair, for instance, affords the ability to stand, to reach something higher than our height, a prop to hold a door open or a barrier to keep one closed. In the gross anatomy lab, students learn the anatomical structure of cadavers by perceiving the affordances of the various atlases, whiteboards, models, labels, incision tools, and other objects to identify anatomical structures, which will serve as a basis for making later clinical judgments. Fountain and Prentice provide insight into the material basis for the practice of clinical judgment, a judgment often described in other inquiries as a process of reasoning from case studies, and thus not sensitive enough to the material, visual, and embodied ways judgment is conducted (Fountain, 2014, p. 99). Petroski’s (1993) work on the development of engineering judgment takes case studies as the primary vehicle for learning judgment from the experience of those who worked on similar problems. While such a perspective is reasonable, it occludes the subtle ways experience with the materials of engineering contributes to the formation of judgment.

Fountain’s and Prentice’s ethnographic analyses echo Ferguson’s (1994) historical research on visual thinking in engineering. Because medical practice and engineering are both directed towards practical ends of producing results in particular rather than general circumstances, it is useful to compare the two perspectives on judgment. Comparing Ferguson (1994) on engineering and Fountain (2014) and Prentice (2013) on anatomy and surgery, it is apparent that both fields rely on visual displays and embodied skills to learn and manipulate physical structures and that both fields not only
use displays to carry out their specific work, but also to exercise judgment. Ferguson emphasizes the power of visual displays for engineering work and notes how many engineers recommend novice engineers observe and participate in the work of machinists, mechanics, and construction workers in order to intuitively feel the way their designs are assembled or used and the properties of their materials (*passim*). Engineers should share to a degree the “knowing hands” of the craftsperson in order to complement the visual understanding of a product or process (Ferguson, 1994, p. 58). All three authors see vision and the body playing a constitutive role in developing judgment.

In this chapter, I will return to these concepts in order to understand how engineering judgment is accomplished. Questions to be answered are: how are judgments made? How do students do it? And what are the roles of the body and technology? In the following pages I describe the recorded actions of engineering students working on a design problem. The description will provide a fine-grained perspective on just how student engineers judge. The focus will be on students coordinating their work, their opinions and ideas, and the resources they use to judge and make decisions. Through an analysis of data, this chapter argues judgment is the accomplishment of participants’ mathematical, analogical, and gestural modes of reasoning to account for inconsistencies, incongruities, or puzzling conclusions and decisions, and to reset the groups’ attention on further tasks.

**How to ‘see’ judgment:**

The selection of the data below will show the subtle work of judgment by student engineers. The selection is a description of six students attempting to calculate the wind force their planned solar tracker would need to withstand. During the process of
calculating, students refine their aims for the solar tracker’s structure based on what the process of writing out the calculations reveals and how, the study will argue, judgment is constituted and spurred.

This chapter adheres closely to a methodology for studying philosophical and epistemological topics in science and technology studies (STS) developed by Lynch (1993). Lynch proposed that the way to understand general and ordinary activities often used in scientific and technological work, like “measuring, counting, depicting, observing, describing, and so forth” is to look in perspicuous settings for “primitive examples” of the action and to see how they are accomplished in situ (Lynch, 1993, p.299-301). Judgment, shrouded as it is in various abstract definitions, is in need of an approach that focuses on its performance rather than its classification. A design course is particularly suitable for this kind of investigation for the reason that judgment inheres in the design process. Additionally, the course is comparatively low-tech, so intelligible to observers, and includes only a few participants dealing with less complex problems in an instructional setting that fosters the practice of designing. Design is more centralized and concrete in this case because it is not distributed across contexts and participants, not interrupted by other activities, and thus offers to analysis a perspicuous setting for studying engineering judgment. Lynch then suggests that the activities be described in detail, and the actions of participants be set down in the sequence of their occurrence, allowing the reader to see how the actions are carried out. Lynch recommends that investigators suspend “judgment on whether the activities of scientists and mathematicians are epistemologically ‘special’” in order to allow the bare, ordinary character of the activities observed to become evident. He recommends that the methods
of analysis be “uniquely adequate” to the setting, meaning, that the investigator uses methods suitable to the case, not overly technical, making the actions of the participants transparent, as well as the observational methods of the researcher. Finally Lynch recommends bringing discussions from the disciplinary literature back into the discussion so a more defined explanation of an activity may displace vaguer ones.

The present chapter, then, investigates students working on a design problem through a visual ethnography and describes how and what they judge to better understand how engineering judgment works, its features, and the implications for teaching engineering judgment. The strip of activity was chosen as an example of the routine work of design where the complexity of judgment was evident. First, the activity will be described as it unfolded, and then the implications of the case study for engineering judgment will be discussed.

**Putting Decision-Making into Practice:**

The development of judgment was built into EMAE 260. Within the first month of the course, Professor Connolly presented a lecture on decision-making. The lecture coincided with the stage of the class where groups had to further clarify some of the design ideas they had generated. In the midst of developing a concept design, students needed to start using formal methods of decision making in order to decide on components of their design and simultaneously fulfill the requirement of the class to use decision-making genres such as Pugh Charts. They also needed to understand the dynamics of group decision making, its drawbacks and advantages. The lecture provided students an overview of decision-making that schematized it as an activity of developing alternative designs or options to components in order to submit ideas to rigorous
intellectual testing. Judgment was defined as the “cognitive or ‘thinking’ aspects of the
decision-making process” (EMAE 260 Decision-Making PP). While being one of the
keywords, judgment was not analyzed in the same way the decision-making process was.
Rather, Professor Connolly repeatedly encouraged students to use their judgment as a
way to make the right decisions. Judgment was an ability all students had to reflect upon
the decisions they had to make and would guide them towards the best decisions.

Decisions making itself was conceived as an art, the art of making choices in the absence
of complete information. Professor Connolly talked of the types of decisions engineers
make: routine, adaptive, and innovative. Each type of decision has a set of conditions
which must be accounted for. The movement of decision-making should ideally be from
conditions of ambiguity to conditions of certainty according to Dr. Connolly’s model.
She then offered tips to making good decisions: follow a checklist, free yourself to
recognize facts, use your intuition, weigh pros and cons, don’t overstress the finality of
your decision, make sure the timing is right, “don’t take no for an answer,” and so on.

She cautioned the class about how shortcuts in decision making can also be traps.
For instance, heuristics, giving disproportionate weight to the first information available
(anchoring), relying on a rigid strategy for decision making, and allowing personal biases
to influence decision making: all of these can be detrimental to decision making by

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13 Adapted from Dr. Connolly’s Power Point: “**Routine problems** are programmed, common problems
with well-defined solutions. They can be solved by rules, procedures, and computer software packages.
They are distinguished by an obvious “best” solution or alternative. **Adaptive problems** are a combination
of moderately unusual and only partially-known problems and alternatives, and are approached by
incremental changes or modifications of past decisions and practices. In order to address them, one must
select from a set of known alternatives, but one is always unsure of the outcomes. **Innovative (non-
programmed) problems** are unusual or ambiguous problems which require unique or creative alternative
solutions. Problems solvers must emphasize radical change, innovation, and brainstorming. When one is
called to solve an innovative problem, one is not sure what the alternatives are, nor whether any will
work.”
foreclosing inquiry into the best decision for a problem. Finally, she offered a few
decision making tools, her favorite being the Pugh Method\textsuperscript{14}. The Pugh Method is way of
making an evaluative matrix that weighs the advantages and disadvantages of design
criteria for a particular customer. Professor Connolly told students that Pugh matrices
should be in their next presentations and then she discussed how they were structured.

As students were introduced to the design process, they were to understand
decision-making as an integral, but distinctive part of that process. In other words,
decision-making was part of design, but it was conceptualized as a definable step in the
process which should be structured by particular displays such as the Pugh matrix. There
were other methods available to students, but the Pugh method was the required for their
presentations. Decision-making came at certain times in the design process and would
have certain effects: decisions would generate alternatives, select components, and
instigate iterations to early points in the design process. Decision-making was structured
by particular methods, methods that were carried out through creating charts to weigh
evaluate criteria. And the guide for these decisions was the cognitive ability of judgment.

While this picture of decision-making provided a helpful way to conceive of and
structure this particular element of the design process, it minimized, or perhaps failed to
account for the way judgment was integral to every facet of design. Judgment was not
just necessary to (say) determine the desirability of chains, steel wire, cables, or hydraulic

\textsuperscript{14} The Pugh Method is method of weighing criteria for different design ideas and is embodied in a chart.
Dieter and Schmidt (2013) explain, “[Stuart] Pugh’s method compares each concept relative to a
reference or datum concept and for each criterion determines whether the concept in question is better
than, poorer than, or about the same as the reference concept (p. 279). In other words, Pugh Charts are
decision matrices used to weigh how well design concepts work relative to each other.
pumps for rotating a solar tracker; judgment generated those options in the first place, spurred the decision to evaluate them, and determined the criteria they should meet.15

Bucciarelli (1994) describes how decision-making strategies fail to structure decision-making in actual situations. In order to evaluate possible design options against desirable criteria, a group of engineers embarked on the Pugh Method, constructing a matrix that weighed one against the other (151). Bucciarelli found the engineers having to debate what exactly were the desirable criteria to weigh the concepts initially, a step for which the Pugh Method does not account. The Pugh Method assumes desirable criteria to be given, but in an engineering design group, differing perspectives on what is important are inevitable as participants come from various areas of expertise and judge from that position what is most relevant to a design project. Such an occurrence is even possible with a relatively homogenous group of student engineers. For instance, when I observed the group creating their Pugh matrix, they had an easier time deciding on criteria because they had derived the criteria from customer requirements. However, the weight given to the criteria, whether aesthetics should be weighed the same as durability for instance, became an issue of contention. For Sedat, aesthetics was of little or no importance, and he could not conceive of why anyone cared what a solar tracker looked like. Bob insisted that no customer wanted anything unsightly, no matter how low the expectations were for solar trackers. Partisans of aesthetics attempted to draw parallels to other consumer

15 The Dieter and Schmidt (2013) textbook for the class has this to say of engineering judgment: “The last and most important ingredient in decision process is judgment. Good judgment cannot be described, but it is an integration of a person’s basic mental processes and ethical standards. Judgment is a highly desirable quality, as evidence by the fact that it is one of the factors usually included in personal evaluation ratings. Judgment is particularly important because most decisional situations are shades of grey rather than either black or white. An important aspect of good judgment is to understand clearly the realities of the situation” (p. 247). This is the only sustained discussion of judgment in the textbook’s 917 pages and it makes no move to integrate judgment into decision-making.
products known for their aesthetic appeal like Apple products and SUVs, while opponents believed (likely unfairly) that rural residents of Southern Ontario do not care whether their energy sources look good. The debate sprung from judgments about what the customer would want and how they should meet those perceived desires. Students drew on their experience and prior knowledge, which in this case resulted in a narrow conception of aesthetics and assumptions about rural populations. Lacking the necessary tools for research on customers of Southern Ontario, knowledge of aesthetics and engineering’s relation to aesthetics, and a diverse perspective from experts in (say) marketing, the students’ judgments were impoverished. What is illuminating, though, is the sociality of judging and how students appeal to their own experience when they lack specific experience with a particular problem.

Bucciarelli (1994) notes that design is a social process and cannot be adequately structured by the logic of the Pugh method. But with that recognition, there is even more distance put between how judgment works and what researchers understand it to be. To imply judgment is just a social phenomenon says very little. It also obscures the materiality through which judgment comes to be, a point illuminated by Fountain (2014) and Prentice (2013). Therefore, this chapter here focuses on a pivotal interaction were judgment is perspicuous, but not predestined by the design process, and particular attention will be paid to the material makeup of the judgment(s). The goal is to see how students made judgments, to say something about their features and how they were sequenced.

One morning towards the middle of the semester, but still early in the design process, six of the seven students (Steven, Bob, Nico, Silvio, Sedat, and Pranav) came
together in a study room to break down the work required for the next several weeks of the assignment. They agreed to begin working on calculating the amount of wind force their solar tracker would need to withstand for customers in southern Ontario, their targeted client area. Students are told in the course lecture to “get things to numbers” in order to provide a clear way for others to understand how their device works, of what it is composed, how much energy will it provide/use, and how much it will cost. The engineering design class, EMAE 260, posits that numbers are the language of engineering.

The idea of turning things into numbers as a goal of the class is testified to in an interview with Dr. Connolly. When asked what EMAE 260 hopes to accomplish, the professor remarked that engineering as way to problem-solve is heightened by her class: “…I think what's a little different about the class that I'm teaching is that sometimes we're trying to figure out how do we quantify something that we don't have a good basis for quantification." Students in EMAE 260 are asked to turn design ideas into calculations, to quantify them, and students are often without a strong basis for quantifying. Meaning, they have the knowledge of the requisite mathematical operations, but the ability to fit and apply their knowledge to underdetermined circumstances provides a unique challenge. Students must research where and how their products will be used and by whom in order to better determine the circumstances they must account for in designing the product. And these conclusions must be understood and presented numerically.

One such circumstance was how sturdy their solar tracker needed to be. The students set themselves the task of calculating just how much force their solar tracker needed to withstand. The group of six surrounded a whiteboard and each had his laptop in
front him. Bob took it upon himself to inscribe the calculations on the whiteboard, asking the rest of the group for the equations and factors.

Figure 4.1: Bob at the whiteboard

They want their solar tracker to withstand the force of 100 mph winds, a number they found from a website selling solar trackers, and characterized as “what competitors guaranteed.” They first try to list all the forces that would act on the solar panel, but settle on the immediate task of determining the weight and shape of the solar panels. Sedat finds an equation on Wikipedia to calculate the force of drag: \( F_D = \frac{1}{2} \rho v^2 C_D A \).

Bob asks members of the group to fill in the variables, and they call out numbers generated from internet searches, which Bob records on the whiteboard, erasing variables and putting numbers in their place.

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16 This is the drag equation and not a formula for determining wind load. The group will soon see their mistake.
After all of the variables were assembled, Bob notes that the numbers are in various units, inches, feet, slugs, pounds, and so on, and need to be consistent. The group then converts the units, and Bob changes the units on the board as conversions are made, and points out which units still needed to be converted. After each unit is converted, he goes back over his changes saying, “This is fine. This is fine. This is fine.” tapping each converted unit with his marker.

The group then starts to calculate the numbers. The calculating is the work of Nico and Steve, primarily. Bob awaits the calculations, standing aside from the whiteboard so Nico and Steve can see the equation. Nico and Steve reach different values. After checking with Bob, it is revealed that Nico neglected to square a number. Steve’s number, 9.2 lbs. of force, is determined as the correct value given the equation on the board.
The conclusion that 9.2 pounds of force is the result of 100 mph winds on square solar panels of 72.2 ft. squared is met with incredulity from Silvio. 

Silvio: “If you think of a hundred mile an hour wind acting on, what is it, what is it, 72.2 square feet of solid surface and it’s just nine pounds of force? That doesn’t seem even remotely possible.”

The tone of Silvio’s question relays to the rest of the group his own thinking process and conclusion on what he has just heard. Each member of the group looks back to the board and starts to question the numbers. Nico wonders if perhaps the 72.2 square feet of surface area is too much. Bob has the group recalculate to check if 72.2 square feet is the correct surface area, and it is. Silvio insisted that Steve’s conclusion is nonsensical. He takes up a marker and designates the tip of the marker as a point of 72.2 square feet and pushes against the marker with his finger to illustrate just how insignificant 9 pounds of force would be.

Figure 4.2: Silvio demonstrating with a marker
Rob suggests the group look up wind load. Pranav already has and gives the two equations for calculating wind load. Bob asks Pranav to explain the values, such as the height of the object. Pranav explains which values are given, which they have to find, and the operations to perform for all of them. After he finishes, Bob states that “This might be air resistance” while tapping the equation on the whiteboard. Nico smiles at the group’s mistake. Bob asks Pranav to calculate the wind load using the equations he found and Pranav does Bob reads the values from the board to Pranav and he calculates them on his computer. After a few moments, he announces the wind force as 2,546.98 pounds. There is an immediate reaction of shock from the group. Nico leans over to look at Pranav’s computer and Pranav recites all of the operations he has performed with the “wind force calculator.”

Bob asks the group what the average wind speed of a hurricane is. The group laughs, but Pranav looks up the average speed, and tells the group the average speed is 138 mph. Bob then taps the whiteboard at the point where 100 mph wind speed is written, the wind speed the group agreed is the maximum speed the solar tracker could endure, and asks “Did we make this number too big?” Silvio immediately reminds the group that the wind speed is arrived at by meeting an industry standard, represented by a solar tracker manufacturer he has researched. Bob replies, the weight for their solar tracker would need to increase if they were to keep to 100 mph. He asks to hear the average wind speed of Southern Ontario and Steven says it is 14 mph. Again, everyone laughs, and Bob asks the group to vote on dropping the wind speed to 40 mph. Nico wonders if that the speed is still too high. Silvio balks at the proposed change. He insists that their solar tracker should meet industry expectations for durability.
Questions about the likelihood of extreme weather in Southern Ontario are asked, and the group looks up the frequencies with which tornados or hurricanes could befall the area. After determining the small likelihood of such a weather event, Steve brings up the fact that the maximum wind speed for the region is 32 mph. Bob goes to the whiteboard and asks for the wind force for 100, 50, and 40 mph. Pranav gives him the numbers, 2,546 lb., 636.7 lb., and 407 lbs., and he writes each on the board. Nico says he cannot imagine what that (meaning, 2,546 lb. of force on a solar panel) is like. Steve offers that it is over a ton. “It’s like you threw a truck at our solar panel,” said Silvio. “Constantly. Constantly throwing a truck at our solar panel,” corrected Bob. The entire group laughs at the absurdity, but they continue to make similar comparisons. Bob notes the difference between 50 mph and 40 mph of wind force amounts to the weight of a large person. Silvio remarks on the difference between 50 and 100 mph being vast and cannot imagine building a solar panel to withstand 100 mph winds. Silvio reminds him they were to design a solar panel not build one.

A debate ensues between Silvio and the rest of the group about whether a solar tracker should be able to survive extreme weather. Bob reasons that if a tornado where to afflict a household, there would be no expectation that the family solar tracker would be still be standing. “In our promotional video, are we going to say that our solar tracker is tornado-proof?” asks Bob. The group again breaks up in laughter. 40 mph is agreed to and the group moves on to discuss the thickness of the solar panels.

**Judgment, Rhetorical Display, and Embodied Common Sense:**

In this section, we see the students trying to figure out wind force. They start with the wrong equation, but eventually find the right one when Silvio realizes the calculations
do not jibe with common sense. The group further refines their calculations by imagining
the force of the wind at different speeds. A striking feature of the activity was the role of
representation, or displays. The description above shows how student engineers use
displays to engender judgment. By making tasks, data, and equations in a space where
each participant can examine the sequence and progress of the group’s activity, points are
discerned where the group activity has gone awry in the eyes of the participants. The
ability to discern points where the group activity has gone wrong rests on students’ ability
to account for conclusions that do not match with the group’s understanding or common
sense. In other words, judgment is the accomplishment of participants’ mathematics,
gesture and analogies to account for inconsistencies, incongruities, or puzzling
conclusions and decisions, and to reset the groups’ attention on further tasks.

There are several incidences in the above description serving as evidence for how
judgment works. The first occurs when Bob sees the need to convert all of the differing
units (inches, slugs, pounds, and feet) into more computable units for wind force. The
display on the whiteboard reflects back to the participants that their task cannot continue
as it had been accomplished up to the present moment. The goal of calculating was
impeded by the various units of measurement, which Bob sees, recognizes, and decides to
have changed. For the participants, the whiteboard “structures mutual orientation to a
shared interactional space (Suchman, 1988, p. 318). It brings the group’s attention to a
space where everyone can see the agreed-upon record of the group’s activity and appraise
its progress in satisfying the task. Bob noticed the impediment and acted in a way to

The word display is used rather than more familiar terms such as representation or inscription to
include not only graphic or written modes of recording or presenting objects, but additionally discursive
or gestural modes of appearance. Additionally, display rather than inscription or representation highlights
the rhetorical function of creating images or appearances (Prelli, 2006).
further the group’s desired activity. He refined the equation to make simpler computations.

The whiteboard serves as the agreed-upon record of the group’s activity and as a guide of their future activity for the task (i.e. which calculations were to be done next), but also works as a resource to settle discrepancies. When Steven and Nico come to different answers for the equation, the group is able to look back at the sequence and have Nico recite his own steps. The two records are compared, with the whiteboard record as the standard and guide for how the computations should have been made. Acting as such a resource, the whiteboard equation can be re-performed to show from where a discrepancy ensued. In this case, Nico failed to square a number, but Steve did not. The whiteboard allows the group to judge the validity of the participants’ actions by checking them against the agreed-upon record of the group’s activity and task.

Objects and gestures to display the concepts, conclusions, and consequences of design were crucial for presenting to the group issues for judgment and resources for making judgments. This is especially evident when Silvio takes up a marker to illustrate how ludicrous it is to believe that 100 mph wind would only generate around 9 lbs. of force. He makes an appeal to ridicule with the marker, advocating for the group to recover their intuitive sense of force over what the equation reveals. The equation on the whiteboard affords a complex judgment here. The students had done the equation correctly, which is the record of the work and the trajectory of their task. The equation as guide for how a task can be completed fails in that role, though, when the equation conflicts with common sense. The inscriptions on the whiteboard then become suspect and open to a different interpretation. They become resources to reassess the sequence of
activity and what the group should be doing. It is at this point that Bob realizes the 
equation they had been working out is incorrect. Silvio’s holding up their conclusion to 
ridicule makes apparent a disjunction between the equation and common sense. Bob 
recognizes the implication of Silvio’s illustration and interrogates the equation. After 
hearing the operations for determining wind load, he sees that the equation the group was 
working out was for “wind resistance.”

Appeals to ridicule bring the group to consider their mathematical conclusions in 
the light of common sense. Perelman and Olbrects-Tyteca (1969) note appeals to ridicule 
as a principle weapon in arguments reinforcing the incompatibility of conclusions that fly 
in the face of accepted opinion (205-206). Ridicule is conservative in the sense that it 
“works towards the preservation of what is accepted,” and exposing one to ridicule is the 
“penalty for blindness and is apparent only to those for whom this blindness is obvious” 
(206). Ridicule reveals what has been overlooked or overstepped in reaching for an 
answer or argument. The common sense violated could be an accepted opinion, a well-
known fact, or some other matter that does not easily admit of questioning. Common 
sense here designates the embodied knowledge of recognizing and understanding the 
consequences of basic physical interactions gained from experience in everyday life. 
Basic physical interactions mean knowledge of density, force, shape, mass, velocity and 
volume inherent in objects and their reactions on other objects. In other words, even if 
Silvio had never experienced 100 mph winds, he knows intuitively it is impossible only 
9lbs. of force would be produced from such a gale on an object. This kind of knowledge 
is anterior and perhaps ancillary to mathematical understanding. Whatever its position, it 
becomes a guiding force in judging the durability of the solar tracker design.
After researching the wind force of 100, 50, and 40 mph winds, the group scrutinizes the numbers and the requirements for design by creating counterfactual scenarios using similes such as thinking of 100 mph of wind force like throwing a truck at a solar tracker. The counterfactual scenarios vivifies the numbers on the whiteboard, prompting the group to visualize the consequences of recommending the solar tracker withstand a certain amount of force. Again, common sense plays a large part in determining the design requirements. It was unnecessary to design a solar tracker able to withstand gale force winds for a place where such standards of durability were unexpected and unlikely to be tested. The role of displays in making judgments changes as the whiteboard becomes “a medium for conception of concrete objects” (Suchman, 1988, p.319). The whiteboard records, figures, and reflects the conceptual objects on which the group deliberates, be they sketches, equations, or agendas. In this particular case dealing with equations, the whiteboard provides a cynosure and point of inception for the group’s examination of incongruities between formulas and common sense, and between options for design requirements. Judgment proceeds through reflecting on and making sense of displays of activity. And judgments are realized or made manifest through the use of displays (visual, embodied, and verbal) that act as the focus on group action (the white board equations) and that make present the workings of judgment which appeal to common sense..

**Conclusion:**

The case study suggests the importance of displays for engineering judgment. Displays provide engineering students a space to examine and reassess the materials and procedures that direct design activity. Students use displays such as whiteboards and
gestures in the preceding case, to see the trajectory of an activity and compare it with the task at hand. This is evident at the point where Bob notes the necessity of converting the various units of measure to simplify the equation. Displays are also resources for recording agreed-upon sequences of activity and judging conclusions based on the adherence to the record. Bob’s adjudication between the two different conclusions of Nico and Steven serve as a point where a display served as the standard for how an action should be carried out. Displays, while being authorities in some situations, can quickly be amended, or shown to be wrong through other kinds of displays. One can imagine the act of sketching, where images are momentary, and are changed in response to emerging concerns. In the case above, the equation’s grip on the process of activity was called into question by Silvio’s appeal to ridicule through his illustration with the marker. Silvio was able judge the mathematical conclusion as against common sense and used rhetoric to gain adherence to his perspective. Finally, displays are resources for the construction of counterfactual scenarios illustrating the consequences of choosing different options. Options are represented and then imaginatively transformed through figurative language appealing to an engineer’s sense of proportion and the satisfaction of requirements.

These conclusions make more concrete several philosophical and insights about engineering judgment and adds to those insights the recognition of the material elements engendering judgment, building on discussions from rhetoric and technical communication on the importance of visualization, displays, and the body in developing and practicing judgment. That judgment is knowing how and when to apply scientific and mathematical knowledge to problems seems justified by the case study, which accords with Ferguson (1994) conception of engineering judgment. The equation was at different
times a record of activity, a guide for activity, and that which impeded satisfaction of the task. Knowing when to trust equations and recognize how to apply them is a matter of judgment as much as technical education. In an increasingly automated and algorithmic engineering world, students need to develop awareness and a ‘feel’ for the engineering object in order to judge whether inputs and outputs are correct or sensible. This feel, attested to by Fountain (2014) and Prentice (2013) comes through developing embodied skills of perception in working with particular cases. However, these new bodily experiences are not the only way to make judgments. In order to understand how to use the objects of a professional practice, to make sense of (say) new mathematical skills and how to apply them, the lived experience of the neophyte has a role to play as well.

Common sense tests the application of new professional skills. One could perhaps go farther and say that judgment and common sense are intimately related. Where one expects to find advanced expertise deciding on the best course of action, it is instead mundane experience informing what the students should do.\(^\text{18}\)

Common sense as embodied experience resonates with Carusi and Hoel’s (2015) concept of the “measuring body”: “[a]s a ‘measuring’ body, the body intervenes into the world; injecting a standard that serves as a point of orientation and institutes a style of seeing and accessing the world” (p. 79). The concept is gleaned from the later works of Merleau-Ponty, building on his idea of ‘flesh’ or the intertwining of subject and object, sensate and sensible. Carusi and Hoel hold that the measuring body is extended to and by

\(^{18}\) Davis (2012) discounts the suggestion of common sense explaining judgment because he associates common sense with a kind of weighing that for him is too metaphorical (p. 806). I do not understand the strong association of weighing with common sense nor would I dismiss the connection because it is metaphorical. Data here suggest common sense as a kind of embodied intuition rhetorically expressed is very much a place to look to understand judgment.
the material environment, and that symbol systems, such as language and mathematics, and technologies are part of that extension (ibid.). They insist the measuring body is bidirectional, that it is a dynamic configuration of the body and environment, emphasizing their reciprocity in being.\(^{19}\) However, in their work and in post-phenomenology in general, this bi-directional dynamic is illustrated through examples of the body’s extension and/or distribution though symbol systems/technology or the incorporation of symbol systems/technology into the body (Carusi and Hoel, 2014; Hoel and Carusi 2015; Rosenberger and Verbeek, 2015; Verbeek, 2005). In the episode above, something different is happening; the body instead acts as a check to a symbol system. What is given through the equation is compared with the body’s experience and found incongruent with embodied common sense. So the dynamic between the body and the equation here is one of reflection, or judgment. The body as a historical entity capable of bringing to bear on a problem an intuition formed through experience, judges the symbol system through sense, finding the conclusion to be nonsensical/nonsensible. The mechanism for communicating this kind of judgment and making it persuasive is a rhetorical one, as attested to by first Silvio’s appeal to ridicule and second by the group’s use of counterfactuals, the “like throwing a truck/car” construction that ultimately determined how the technical requirement should be satisfied.\(^{20}\)

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\(^{19}\) They note, following Merleau-Ponty, they are not saying that everything is “one” or that subject and object are not real. Substance is divergent through the non-coincidence of the body with itself, such as the inability to touch and be touched at the same time (Carusi & Hoel, 2014; Hoel & Carusi 2015). This non-coincidence enacts the relationship between subject and object.

\(^{20}\) A comparison of Carusi and Hoel’s (2014) opens up another feature of judgment. Carusi and Hoel use the example of computational biology to show how the qualitative (mapped onto subjective vision) and the quantitative (mapped onto computation/mathematical objectivity) methods form a ‘mesh’ of observation where biological phenomena are seen according to two different ontologies. Thus, biological phenomena are ‘seen’ from both subjective and objective perspectives, and the object can be understood both qualitatively and quantitatively in the same process of rendering. Granting for the sake of argument Carusi and Hoel’s characterization of ontology, in the situation of problem-solving, the dynamic between
Knowing when to deploy common sense is a perceptual ability. Several authors discussing judgment emphasize further its perceptual aspect (Ferguson, 1994; Holt, 1997; Vincenti, 1990). The ability to see something awry and problematic is a perceptual skill necessary to exercise judgment: “Salient features calling for practical reason do not spring to the eye already tagged for recognition…Rather we have to pick them out, and this involves the ability to see fine detail and nuance and the ability to discern the difference between this situation and others that to the inexperienced eye might seem the same” (Dunne & Pendlebury, 2003, p. 207). This chapter not only provides an example of seeing what is in need of judging, but also shows how what is seen by one is made present for the group. In other words, judgment in the engineering design context is less a mute ability of perception, and more an activity unto itself requiring recognition of an issue, appeals to reason, and demonstrations for the benefit of others. In situations where no one person is completely invested with the power of arbitration (as in design), the need to argue for and demonstrate a judgment, strengthens judgment’s force and promotes cooperation. In sum, good judgment in design requires a rhetorical approach to judgment.

Finally, the case study shows the creative aspect of engineering judgment. It is Davis’s (2012) contention that judgment is in large part creative, that judgment is about constructing of possibilities under constraints (pp. 806-807). The counterfactual scenarios perception (subjective vision) and mathematics (objection computation) looks differently. Rather than meshing, Silvio perceives the necessity to decouple the group’s understanding and vision of wind force through the equation in order to interject the body’s knowledge of what an appropriate conclusion would be. The body as a subjective perceiving and reflecting entity undoes the mesh in order to further scrutinize the situation. His appeal to ridicule puts the findings of common sense before the group, and the findings of his subjective perceiving body become objective through the appeal to common sense. In other words, subjective vision becomes objective reasoning in order to correct quantitative reasoning. It seems judgment arbitrates between subjective and objective perspectives within an activity, and the process of making those perspectival changes is a rhetorical process.
of the students offer ways to discount choices, clearing away alternatives by imagining their consequences. The construction of counterfactual scenarios serve as persuasive reasons for making decisions. And again, the importance of displays come to the fore. Displays afford participants stable-for-now objects amendable to conceptual, mathematical, or rhetorical manipulation, allowing judgments to be formed and reflected upon. New alternatives or solutions following judgment can be recorded and refined by being inscribed and displayed.

The integral role of displays in engineering judgment speaks to recent work in engineering education focusing on the importance of representations (Johri, Wolf, &Olds, 2013; Juhl & Lindegaard, 2013). Johri, Wolf, and Olds (2013) contend engineering problem-solving is fundamentally a matter of using representations (pp. 2-3). Engineers are surrounded by computer screens, drawings, graphs, equations, sketches, reports, memos, Power Point Presentations, and more. Engineers see and manipulate their professional objects through representational media or displays (Henderson, 1999; Suchman, 2000). The connection of the mediated world of engineering with the development of engineering judgment is implied by scholarly emphases on perception and non-verbal thinking, but the constitutive role of displays has not being fully recognized, and instead engineering judgment is often restricted to abstract discussions about relating general knowledge to particular situations. Or, as in the case of EMAE 260, judgment is relegated to an important, but vague ability to think. What the above case study reveals is how judgment is immanent in mundane engineering work, and how common tools of engineering serve as the basis for developing a type of judgment that
could be called engineering judgment. More effort needs to be expended to think of pedagogical strategies to make judgment a fully realized topic in the classroom.

For engineering educators, the call for students to exercise judgment can be buttressed by reminding students of the importance of displays to record group activity, manipulate conceptual objects, and create rhetorical appeals to persuade participants of design decisions. Perhaps more importantly, the chapter exhibits that judgment is needed for students to recognize when they are on the wrong track, using the wrong tools, or coming to suspicious answers. In the matter of using the wrong equation as described above, the mistake can be accounted to the student’s less than mastery of calculating force. But that would miss the point that as students learn the science, mathematics, and tools of engineering, they still must develop the ability to judge the correctness and fit of applying their learning to real situations.

The attention students are taught in the classroom is worked through in the social order of teamwork, through attunement. In the classroom, they learn the tasks and texts to guide decision-making, the appropriate times for making decisions, and the skills to carry them out. They are taught to attend to how decisions are integrated into design, their purpose in prompting iteration, and the factors to consider in making decisions. For actual decision-making something more is needed. In group work, in the practical engagement with design and the genres and formulas for decision making, students learn judgment, the reflective guide for decision-making. In activity, in working with constraints, in testing conclusions, and arguing over possibilities, judgment is engendered; a rhetorical perceptive skill that displays and interrogates displays and tasks. Judgment is a thoroughly practical, perspective driven activity of assessing and
manipulating materials to reveal their affordances for action and their barriers to sensible conclusions.
Chapter 5: Design and Genre: Craft Pride in the Engineering Design Presentation

There is an economist joke that goes: Students are the only people who still believe in the labor theory of value: “A ‘B!’ But I worked really hard!” Like most academic jokes it’s not very funny, but it does, however, express a reality about how students sometimes feel towards the work they produce, the effort that goes into it, and the way it’s evaluated. My purpose here is not, however, to discuss student demands for better grades, but to discuss how students feel about the labor they expend in composing genres. When students learn a new genre, they are also learning how their labor and effort are valued through particular expressions. Genre writing augments or minimizes antecedent activity; its constraints call for labor expansion or compression according to the action it mediates. This a fundamental feature of genres and a fundamental experience for students learning to attend like engineers.

For the student engineers I observed, to see their work compressed, concentrated, and edited was a frustrating process. By learning the genres of the engineering profession, students saw the fruition of their work adumbrated in order to meet the demands of the design classroom, which were ostensibly the demands they were to encounter in careers as professional engineers. These students’ frustrations remind us that learning genres is not just about gaining entrance into professional or social participation; it also is about the loss or letting go of old ways of conceiving practice. This chapter uses Rhetorical Genre Theory (RGS) to understand data revealing the variety of student discontent in composing final presentations for EMAE 260. RGS takes genres as social action, as Miller (1994a) famously described it, and examines the processes and
consequences of composing genres that entail certain kinds of expression over others. For instance, the patient intake sheet at a doctor’s office will allow for different kinds of information depending on the doctor being a dentist, a pediatrician, or psychiatrist (see Devitt, Bawarshi, & Reiff, 2003). Certain information is relevant and prompted for, and other information is not accommodated. So goes genre writing in all social and professional situations.

Near the end of my fieldwork and my period of data collection, I was told by participants of their frustration with how the new genres they were learning (specifically the genre set making up their final presentations) failed to capture the hard work they put in and the extent of their knowledge about their designs. In what was the first design project for many of the students, and certainly the longest and most labor intensive design project any of them had hitherto undertaken, students were asked to present their work in a presentation that included several typical professional engineering genres. The student presentations were presented through Power Point and typically were given by several members of a group. These texts displayed the decisions-making processes and conclusions of the group regarding make/buy decisions, analyses of potential failures, cost, group member responsibilities, and a theory of operations. They also included CAD drawings and one depiction of the fully assembled design. While these genres revealed the dynamics of the groups’ activities and the groups’ adherence to the demands of the professionalizing classroom, they constrained the students’ expression of their design as they conceived it.

The genre set of the presentation included slides showing team goals, customer and derived requirements, a theory of operations, make/buy decisions for materials, slides
depicting a bill of materials, the manufacturing costs, technical equations, an FMEA (Failure Modes and Effects Analysis), and an updated Gantt chart. All in addition to two slides for the design assembly. The presentation foregrounded a clear statement of goals and how they were achieved (goals, requirements, Gantt chart), decision-making for materials and manufacturing, clearly supported technical specifications (in the form of technical equations, theory of operations, and the FMEA), and CAD proficiency. The presentation was called the detailed design, meaning it was to display the design in detail. Details referred to attention to how the design could be traced back to the customer requirements, how it could be made and of what, how much it could cost, how it could work, and whether it was safe. The presentation deeply contextualizes the design artifact in a matrix of constraints, demonstrating its embeddedness in various sociotechnical relationships of manufacturing, budgeting, and regulation. The detail design is not a detailed presentation of the design artifact, but a presentation of how student engineers had attended to professional engineering constraints.

Examining these generic constraints sheds light on a side of genre learning not often discussed. That learning a genre shapes knowledge is widely understood (Bazerman, 1988; 1994), but what about the kinds of attitudes and motives towards engineering practice that are reformed, recalibrated, transformed, or stripped away as students move forward in a process of professionalization that starts early in college, is supplemented and filled out by service-learning projects, internships, co-ops and the like, and then is fast-tracked upon becoming employed as an engineer? In taking up these questions, this chapter closes the process charted so far in the dissertation. Students learn to attend to engineering in the classroom through texts and discourse that attempt to
structure how they design and make decisions. In actual group work, students do not reliably reproduce this attention, but instead develop a relationship to design that is personal. The structures they learn in class, as flexible as they are, do not fit onto, and therefore fail to dictate, the order of designing structured by interactions between group members. There is a tension between the education of attention in the classroom and the attunement to design occurring in group work, the latter is student-centered while the former is professional.

The tension becomes quite palpable in transferring the results of design work into classroom presentations. Student see hard choices must be made and these choices affect how their work is presented, how credit is portioned, how credit is viewed, and how it is valued. Students have to take the process and product of attunement and make it intelligible for the professional attention of the classroom. This chiasmic process is how students learn to attend to engineering problems like professional engineers. This chapter discusses the less noticed consequences of this process through the critical vocabulary of RGS and concludes by demonstrating students have an inadequate understanding of genre and engineering practice. They see the presentation as a type of window display of their effort and see engineering practice as composed of two distinct sequential activities, designing and writing, rather than seeing design and engineering writing as integrated, interdependent activities.

**Engineering Writing and Genre:**

It is a cliché that engineers do not like to write and are not good writers. Like most clichés about professional communities, it is embraced by some members to a point, but on the whole, it is not true. Engineers need to communicate constantly and that is
facilitated by writing. According to Louis Bucciarelli (1994), however, “only a few”
engineers actually enjoy composing documentation, the group of texts that represent the
design process: its decisions, its conclusions, and its components (p. 195; Winsor, 2006).
For Bucciarelli, documentation “reads like an obituary;” it is “a reflection of the
inadequacy of object-world voice and the written text to capture the object as social
process both in its design and in its performance out in the world.” (195). Documentation
as a record of the dynamic social actions and textual interactions from up and down
hierarchies within organizations and with customers and officials without, cannot help
but seem lifeless in comparison with the design process itself. Documents of the design
process fail to represent the energy, contingency, ambiguity, and vitality of the design
process. This stability is, of course, an important feature of genres, the function of
making intense or laborious activity structured and communicable (Schryer, 1993).

While the translation of the design process into the paper trail of documentation
entails a loss of a certain quality of vivacity, design documents are often invigorated
when put into the service of guidance for designs and design arguments. Documentation
is generic in that they come to serve as typified responses to recurrent social situations
(Miller 1994a): they close the design process, and but are potentially integrated into
future design processes by other members of the organization as resources to solve a
problem, or as record of where something may have gone wrong. In the engineering
design classroom, documentation functions differently. Documentation is simplified and
enfolded into the design presentation, changing its generic function and thus, changing
the intentions of its users. A significant function of the design presentation is to
demonstrate and perform the values of engineering as produced through the course. The
design presentation is an epideictic performance in that it shows the teacher and class the uptake of the discipline’s reasoning, appropriate dispositions, and generic forms (Fountain, 2014; Sullivan, 1994). This specie of rhetoric is mixed with the deliberative as teacher and class play the part of a group interested as to whether the design is useful. While both species are in play, the epideictic is the foremost because the driving force of the class is to display a professionalized attention to engineering, while the deliberative serves as a warrant for assigning grades and addressing critiques.

The design presentation genre set has other functions as well. The presentation’s forms extend the student’s disciplinary knowledge of the field, each genre populating a constellation of actions and responses to situations that are themselves changing with context, participants, and time (Artemeva, 2008; Tardy, 2009; Winsor, 2003). Genre not only regulates these situations, but also constitutes them; genres are both structuring actions within situations and the situations themselves (Bawarshi, 2003; Miller, 1994b; Schryer, Lingard, & Spafford; 2007). Experience with and through genres also builds rhetorical knowledge as new genres bring together new audiences and require new contents and modes for identification and persuasion in both school and work (Tardy, 2009; Winsor, 1996). At the cognitive level, genre experience also shapes the perceptions and concepts of students. New generic tools facilitating tasks and instantiating information push existing practices and knowledges into emerging and developing conceptual categories, categories that are themselves positioned by still broader categories affected and organized by political, social, and economic factors (Bazerman 2009; Russell & Harms, 2010).
The genre of the engineering design presentation, specifically, introduces students into thinking, talking, writing and designing like professional engineers. Presentations allow students to try on the engineering persona and act within the kind of genre typical of professional engineering practice (Dannels, 2000). However, though the design presentation speaks to professional exigencies, it is more responsive to the exigencies of a school context. This tension produces contradictions between the activity systems of school and work, as students try to serve two masters, so to speak (Dannels, 2003; Russell, 1997). While this dilemma seems to suggest that students are caught in a bind between acting within and towards school or work activity systems, the bind is not so restrictive that students cannot negotiate between the systems, meeting the significant rhetorical demands of each by translating and communicating their work for both audiences, gaining what Dannels (2009) calls “relational genre knowledge.” Relational genre knowledge is a knowledge that interacts with both school and work activity systems, as well as acting as a bridge between the two as the school concerns are shed and the work concerns become typical and recurring.

While the concept of relational genre knowledge may potentially point to a way to focus and explain the incremental rhetorical, social, and cognitive steps in genre learning and development engineering students take through college to employment, it is, like many analytical tools for understanding professionalization, one that is often looking forward towards what students are to take on and not what they leave behind. Of course, if the goal is to teach students to be competent professional rhetors--speaking and writing eloquently and ethically within institutions that will be morally compromising at times--, then it is understandable why there are few glances cast backward. However, recently,
more researchers have focused on how genres constrain and discipline users (Dryer, 2008), disperse or consolidate power (Coe, Lingard, & Teslenko, 2002; Winsor, 2003), and silence outside voices (Applegarth, 2012; Randazzo, 2015). Paré (2002), for instance, discusses the difficulties a group of Inuit social workers experienced when taking up the detached professional persona of the social worker while working within the intimate culture of the Inuit community. The new social workers felt uncomfortable recording the struggles of their friends and family for the benefit of the white colonial state apparatus. Part of their work was the compiling of detailed records, the writing of which felt like prying and spying to the novices. But in order to perform their work, they had to address their clients with the prescribed attitude and meet the genre requirements of the record. In order to compose genres for professional situations and to inhabit the professional identity certain genre work calls for, writers must succumb to demands on their attitudes and adopt particular motivations suitable to a profession.

I argue that this feature of genre learning, the recalibration of antecedent attitudes in order to respond to educational and professional exigencies, can reveal what professional genres strip away. Following an outline of the methodology for the study, I will examine students’ interview statements on what gets left behind by being introduced to new genres.

The data for this chapter are primarily from the interviews I conducted with students and the professor throughout the semester. The interviews were semi-structured and ranged from around one hour to twenty minutes. Pranav, Sedat, Silvio, and Benny, whose interviews form the bulk of the data analyzed here, were members of the group, SunTrac, whose work I video recorded. Bill, a sophomore, was a member of another
group and volunteered to be interviewed. I also collected every group’s final presentation Power Point to compare with their description of the presentation, and observed their presentations in class. By putting this data in conversation with Rhetorical Genre Studies and related research, I saw how student expressions of disappointment, regret, loss, and waste in the translation of design work into the design presentation genre could expand the understanding of genres as professionalizing and socializing tools, and how genres are perceived and processed by students learning to write in the disciplines.

**Approaches to Genre:**

In the course of a wide-ranging interview with Professor Connolly, I asked what she looked for in student presentations. She noted that presentation skills such as confident and articulate oral communication were important. She also wanted to see that students had followed the templates that she had provided, that they used these templates to structure their design tasks. Additionally, Dr. Connolly revealed how important it was for students to understand how their engineering is taken up and presented in organizations:

*Prof: So that's basically what I look for, you know, I'm looking for improvement over the semester, I'm looking for the ability to follow instructions. And in every case too, when I give them a list of the things that I want, it's because that means they've got to dig down and say ok now we really have to do an economic analysis because she's asking us for a cost estimate.*

*JSW: Right.*

*Prof: Or to show that that we've done the calculations so that our derived requirements which we came up with are met with the design we have come up with.*

*JSW: hmhm*

*Prof: So there’s gotta be, behind every slide probably hours of work.*

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21 The interview transcriptions hew to the interviewer’s actual words. Edits where made when the conversational sequence would have marred the speaker’s sense and where there were digressions.
JSW: Sure, absolutely.

Prof: I think that's hard for people to understand sometimes too, you know? [...] When I ran a materials testing group I had an engineer do a lot of work for me on corrosion and it was close to 18 months’ worth of work and it showed up as one little table in a report [holds up hands to form a square with both sets of thumbs and pointers] like this.

JSW: Sure, yeah.

Prof: But it was important data, so you know, the whole idea of generating the data and boiling it down to a point to where someone can look at it and make a decision from it.

JSW: hmm

Prof: That's the other thing too, this is really, you know, what they need to realize is that they can guide decisions for their management by being able to present data clearly.

In addition to expecting a level of professional performance and the meeting of genre expectations in displays of texts reflecting the student groups’ activity, the professor describes a process she wants the students to undergo. This process of composing for engineering presentations involves the ability to take months and months of work and compress it into a concentrated textual form. The form needs to be cleansed of the messiness through which the data emerged and made into something comprehensible to serve as evidence in decision making. In other words, for a successful presentation, students needed to understand how to recontextualize their work through genre.

Recontextualization means taking information from one context and making it suitable for another (Bawarshi & Reiff, 2010, p. 93). However, recontextualization is not a matter of mere translation, but a transformation of data, discourse, and/or images for a new audience that is shaped by different dynamics. Collecting, recording and discussing data in the field and giving a presentation in the boardroom are radically different activities, and the difference impacts what information is expected and how it is received.
In addition to genre learning including the skill of recontextualization, the presentation teaches students how genres economize work. Students must understand that the purpose of their activity is to provide evidence for decisions, and this evidence has certain allowable textual forms that address defined relevancies. Engineering work is part of a business, part of industry, so its fruition must be consumable to other areas of specialty. As will be discussed below, this fact becomes a major point of contention. As the genre set simulates the genres of professional engineering, it allows only certain types of expression. This situation can cause students to feel resentful, and even alienated from the labor of design work.

The generic function of inscriptions for the engineering presentation are to make available for evaluation the work of the group. They are also to experience the process of engineering composition, a process where months of effort may add up to just a few numbers in the corner of a presentation slide. The professor’s anecdote references the kind of work that goes on in organizations where workers are connected through multimodal genres systems in a still greater ecology of interdependent organizations (Spinuzzi & Zachary, 2000): one group of material scientists test the corrosion rates of various alloys for months on end to make a data point for the options of materials in manufacturing an industrial part. Of course, students are not part of such an ecology. Their design decisions will not extend past the classroom context and will meet no other immediate need than that of the teacher’s for evaluation. The genre set is contrary in that it originates and is for a professional context, but speaks to a school context. Additionally, the constraints the students work under and the demands of the rhetorical situation are purposefully alien to students so that their normal ways of conceiving of
engineering can be disrupted. Dr. Connolly felt it was important to for them struggle to with these demands. In interviews she often made use of constructions such as “Trying to get students to see”, or “Get them to think,” signaling her efforts for students go through realizations about the situated and rhetorical nature of professional engineering work.

Both professor and student understood the stakes of the rhetorical situation to which the presentation responds, though students were motivated by more than the getting the teacher’s approval and following her rubric. Several students I interviewed desired something more from the presentation, more space to express their relationship with the design.

In the absence of their design being taken seriously for manufacturing or their calculations being the basis for anything other than a sound mathematics demonstration, students imbued their designs with a kind of pride that failed to transfer fully from the effort in designing to the presentation of the design. In fact, in the selection of talk above and throughout the interview with the professor, the student designs themselves were hardly mentioned. This is not to say that the professor cared nothing for the designs, because that would be false, but rather that her interests in student work were motivated by tracking improvement in students’ ability to be attentive to the demands of the genre set. This attention meant demonstrating the relational genre knowledge to both satisfy the demands of the school project while addressing the kinds of concerns professional engineering will have. Student attention must oscillate between the immediate school context and forward to the professional engineering concerns that are not yet actual (see Lymer, 2009).

In the process of forging this genre attention, students must background some
aspects of their engineering designs. In doing so, different motivations for designing are frustrated as they are found to not fit with the genres students are expected to work under. Although, not all generic restraints are frustrating. Pranav found the logic of the presentation sensible and his motivation coincides with the aims of Professor Connolly.

*JSW:* [what does the professor want to see?]

Pranav: *I think she clearly wanted to see what have you learned. How can we implement everything from the lectures into the process so that it shows me that you learned how to use these tools. Because again, the tools are the most important things for going through that process successfully and making sure you make the right decisions. So showing her that you were able to use these tools effectively was key--because she didn't want the nitty-gritty details of how many screws were in the picture, a list of ten different materials you wanted to look at all the bill of materials... she just clearly wanted to see, can you use these tools. That is a success from her standpoint: seeing, ok, did they learn the material.*

Pranav expresses a desire for his group’s design of a solar tracker to speak to the requirements of the assignment. The details of the parts that go into the design and the various possible materials considered from the start of the assignment, can be forgotten because they are unnecessary to represent for the teacher. When constructing a design for a solar tracker (a device he was not familiar with before the assignment) while also taking four or five other classes, the economizing effects of genre are welcome, because he and his group only have to attend to so many aspects of the design.

But in economizing details, genres can make much of the effort seem all for naught. Sedat expresses this feeling when he finds that the expectations for the genre presentation in the current course put much less emphasis on the design itself than the previous course of which the present one is a continuation.

*Sedat:* *I feel we kinda put in more work into project than the final representation. Actually like...*

*JSW:* *How do you mean?*
Sedat: There were just like a lot of other technical things.

JSW: Like what for instance?

Sedat: Well, a lot of other technical things we would have done, but we didn't because we didn't have space to put in technical information [...] Like, determining how much [wind force and weight] the thing could actually handle [...] We were gonna do all these calculations

JSW: I remember when you guys started thinking about that

Sedat: We couldn't actually put the calculations in it so, we figured, we got a rough estimate that it'd be pretty small so we just [inaudible] I don't know... there were also a lot of little details in Solid Works [the CAD software] [...] like we just showed a full assembly, whereas for our projects in [the previous class, EMAE 160] where we were presenting [...] we had the drawings of the full assembly and the drawing of each part. And then we had the, uh, I forget what it's called... but like the drawings that showed all the tolerances, all that kind of thing, all those kinds of things, and I was kind of expecting that kind of process [...] I was kind of surprised by that. Obviously we didn't have time to do that.

JSW: So her directions, you know, changed what you could actually show.

Sedat: yeah.

Sedat understands that the design presentation in the current course has taken on different significances and it now responds to different expectations. Disciplinary knowledge has changed and what his writing previously accounted for is no longer required (Stevens et al., 2008). Now the details of the design are deemphasized so that other professional generic forms can be included and practiced. The first class, EMAE 160, focused on CAD proficiency, so full assembly drawings were the centerpiece of the final design presentations. In the current class, CAD proficiency is taken for granted, as is the ability to make all of the technical calculations and decisions, or at least those calculations and decisions that are not directly requested by the professor. The genre of the design presentation responds to a new set of requirements for professionalization, and the technical skills that were once the pride of the student and the mark of good design to the
professor are filtered out by the generic form of the presentation so that other
competencies and proficiencies can be gleaned.

As I have mentioned above, the introduction to new genres entails a change in the
way work is valued. When students value engineering design work for different reasons
than professors, a clash of motives and expectations occurs, possibly resulting in
frustrations on both sides. In the excerpt below, Silvio voices his disappointment over the
genre of the design presentation precluding the value he thinks is important to design
work:

Silvio: *We basically wanted to express what work we did, what work we put into ...the
thing is, I think we expressed the work we put into everything around the project, but not
the actual, physical design of the project. The design only got two slides ...just like the
final rendering.*

JSW: Yeah. And that took, like, several months

Silvio: *That was a little frustrating. We kinda wanted to express the hard work we put
into this design and for the rest of it; we just kinda wanted to get the rubric filled out. All
the tasks she wanted to have us completed, we wanted to have those completed. I think we
mainly focused on the design and the rest of it, I think we kinda wanted it to have it done.*

JSW: What do you think [the professor] wanted to see [from the final design
presentation]?

Silvio: *I think the fact that she wanted only two slides for the design that she really didn't
care about---well, I think she cared about how you came about your decision making and
everything else. But I don't think she cared about the project, the final design of your
specific project. She wanted to know about everything that went into it, like the FMEA,
charts, the decision matrix, and all that other stuff.*

JSW: Right

Silvio: *I think that's all I want to say.*

Silvio is quite explicit in his feelings towards the design presentation. The
elements the professor wants to see are the new genres that the class introduces: the
FMEA (Failure Mode and Effect analysis), Gantt charts, Decision Matrices, Pugh Charts,
and cost analyses. The physical design project takes up two slides, but it took nearly all of
the group’s time to create the design. To make a solar tracker without having ever seen
one prior, without organizational support like they would have at an engineering firm,
and most importantly, without actual mechanical engineering expertise, designing a solar
tracker that the professor can recognize as a viable design was daunting. Silvio and his
group did design a solar tracker and were quite proud of the fact. But the pride in the
artifact is in a sense disallowed by the genre constraints of the design course. Expression
of what the students valued were at odds with what the teacher valued and needed to
inculcate and evaluate. Silvio and his group wanted the design to stand for the group’s
progress and reasoning, rather than the other forms of the genre set. The other forms were
simply points on a rubric. It is not that he did not understand what was expected of his
group and reasons for it. He grasped that the professional shaping produced by exposure
and use of the professions’ genres was the effect the professor was searching for: “so they
could compete with other students in their co-op,” Professor Connolly explained to me in
her interview. But Silvio finds the forms of the genre direct attention away from the
design, the object he believes should be most prized by the professor.

Another point Silvio touches upon is the distinction he sees between different
forms within the genre set. Echoing Bucciarelli’s (1994) feeling towards documentation,
Silvio saw the design as the important thing to work on and felt the other genres simply
had to be filled out when the date for the presentation approached. Notice now Silvio
perceives the presentation has a sequence of parts rather than a unified response to a
situation. There are the forms from the rubric and there are the slides for the design. For
Silvio, one has more weight because it was more time and effort intensive. One, the
design, is seen as essential and central and the other, the rubric requirements, are peripheral, and Silvio thinks it is somewhat perverse that they are of such concern for the professor at the expense of the design. This points to a disjunction between the skills the classroom is teaching and what Silvio understand those skills to be. The point will be elaborated below, but not before the communal potential of the presentation is broached.

Bill, a student in another group working on a chainless bicycle and not a solar tracker, desired a larger representational capacity for the design. For Bill, the design is a visual argument that can speak volumes. If the design was given full attention within the genre it could do the revealing work of the other forms, it could show the group’s attention to detail, users, and ingenuity. Bill knows grades come first, and he, like Silvio, Pranav, and Sedat will not sacrifice his grade in order to fully display his craft pride. However, he expresses disappointment in the seeming inefficiency of writing so many generic forms when the design can potentially do most of the arguing itself:

**JSW: [aims and goals of the final design presentation?]**

**Bill: Um, again, Greg wants to present everything on the checklist [the template the professor handed out for the final design].**

**JSW: Sure.**

**Bill: Nothing more. Nothing less, nothing more.**

**JSW: Gotcha.**

**Bill: And that's fine. He's the TL [Team Lead], he can do what he wants. I will listen to him, that's how it works.**

**JSW: Right.**

Bill is referring to Greg’s role as team leader of his group. Greg has instilled in his team the goal of working to meet the rubric’s requirements. Nothing is prized above meeting the presentation requirements for Greg. From Bill’s report, he seems to
understand the genre of the presentation as meeting a specific situation requiring specific information. Bill, however, in his role as a designer, finds the genre constraints both overbearing and even inefficient.

Bill: I would have like to see a more full design report.

JSW: What do you mean by that?

Bill: Let's say I have an assembly that has four parts: in order, to display that assembly, I need a minimum of seven drawings, I need full views of each of the individual parts, a full view of the assembly, and then the assembly in shadow view with everything else. And then maybe an attachment drawing.

JSW: Right, but that's for if someone wanted to be able to manufacture that thing.

Bill: But there's...there's a lot ot it...there's alot of nuances in design that if you just look at an exploded view drawing.

JSW: Yeah

Bill: You wouldn't see.

JSW: No, certainly not me.

Bill: But it's like no one would see. It's like, you know, if example Andre [fellow group member] and I spent an hour and a half figuring out the gear tooth size. We literally took an hour an half trying to figure out, how deep and how wide [models a gear tooth with thumb and forefinger] the teeth need to be.

JSW: Yeah, my group was, is, agonizing over what size to make a worm gear.

Bill: Yeah exactly, so it’s like, that's a nuance in the design where if I had to show you assembly, like, you're gonna have no idea the effort that when into that. Or for example, we have knida like a system of gear, so that when you pedal, it feels like it would on a regular bicycle.

JSW: Oh cool.

Bill: I spent probably two hours, figuring out how to make those gears. An assembly drawing doesn't have dimensions on it. You're not gonna know that the reason that gear is so big, 'cause like the design looks kinda stupid if you don't know. So I need to now verbally explain to her the reason this gear is so big and the reason it's placed the way it is is so that when you pedal you get the equivalent pedal stroke [mimes pedal stroke]. Becuase if you just did one to one, it would be impossible to pedal the bike.
JSW: So if you did a full design report, you wouldn't need to explain your drawings?

Bill: I would not.. I could literally not have a single drawing in my presentation, except maybe an exploded assembly drawing, maybe. And she should understand everything I’m talking about because she would have a packet of all the drawings and I could say refer to this drawing and you will know exactly what I’m talking about.

JSW: oh ok

Bill: But the bummer is, that's EMAE 360 not EMAE 260 so I'm thiking a little too far ahead.

Bill’s justification for a full design report is it allows for nuance to be expressed. A full design can display the full effort that went into designing. In other words, the bigger the inscription, the less labor is compressed and filtered in its inscribing. The usability of the design becomes apparent. The design decisions about size and parts are made obvious. And finally, the full design report saves his group and him time in explaining themselves and their work. The full design report is the model of efficiency and economy for the design presentation. It is a way to fully value and comprehend the labor that went into design and appreciate the group’s care in designing. Bill’s conception of design as self-evident might seem problematic, but he projects a kind of engineering kinship between the professor and his group. As engineers, they can evaluate together the design from just the drawings, all questions of group reasoning and progress—those questions the decision matrices, Gantt chart, etc. answer -- can be answered through discussing the design. In its inscriptions, the design indexes the group’s effort, its aesthetic, its care, and its values, according to Bill. The full design report is a “discursive site” where Bill’s desire to express the pride in his craftsmanship meets all the expectations and desires of the professor (Bawarshi, 2003, p. 17). In other words, Bill wanted to have a conversation
about the drawings, and to forego the other genres. Though both parties, Professor Connolly and Bill have different motives and desires, the full design report with its dimensions and multiple perspectives can mediate between those differences and negotiate exigencies of the classroom and the desires of the craftsperson. Bill seeks to commune with the professor through drawings rather than charts or graphs because he wants the design presentation to look more like the design process, a dialogic process where participants come to an understanding through referring to images. The presentation is not loose enough and fails to provide space for the best kind of interaction, in Bill’s opinion.

Many educators would want to caution Bill that designs, no matter how detailed cannot speak for themselves, and always need to be contextualized and compared with something relevant (Tufte, 1997). In fact, I believe that is the motive of the professor and one of the many reasons the design presentation includes so many other generic forms in addition to and at the expense of the design. The students, though, while understanding what the other generic forms can do and why they should be practiced in them, still regret the loss of effort they see in composing those genres. This expression of frustration, loss, disappointment, surprise, and waste show the contested nature of genre, the clashes in motives and desires played out in fulfilling formal requirements.

Bill and the other students quoted here express a different way of thinking about what’s important to the work of design, the work of a design class, and by extension the work of engineering. Sedat and Silvio felt the genre set did not allow space for certain expressions of work. There was not enough of a space to demonstrate the effort that went into the design. Sedat understood this as a change in disciplinary knowledge from the
first class of the design sequence to the present one. Silvio expressed dismay at this change as well, and felt the emphasis on the other forms at the expense of the design, devalued the design and by extension the effort put into it. Bill saw the genre set as failing to replicate what he believed to be a more authentic design situation. The requirements got in the way of one designer talking to another, as he imagined it. Had he the genre space and a particular kind of interactional floor, he could better communicate the design he made, communicate its nuance, and reveal the labor that made it what it is. This impatience with allowable genre space provoked anxiety in students over the professor’s uptake of their effort. In other words, students did not trust the genre set to respond to the situation as they conceived of it, thinking the professor could not tell from the expected forms just how hard they had worked. The genre space did not provide them with enough textual opportunities to display their work.

Student unhappiness with the forms the genre assumes and values, and the consequent letting go of their own values, points out a sacrifice students are asked to make in the disciplines where professional development is thoroughly intertwined with higher education. It is important for educators and researchers in technical communication, engineering education, genre studies and rhetoricians to examine critically this common occurrence and ask why it happens.

Genre for the Engineering Design Classroom:

The interview data suggest students labor under presumptions about engineering genres and engineering in general. Firstly, students think of genres as forms through which to display their work rather than opportunities for social action. Even Bill, who seemed to understand best the potential for interaction of the presentation, thought of the
genre as a window to display his effort. Sedat and Silvio seemed to share a similar viewpoint. The idea of the genre as a window displaying effort runs counter to the intentions of Professor Connolly had for the presentation. She understood genre’s economizing power, the power to make months of scientific labor into a small box on a Power Point. Professor Connolly possessed a rhetorical understanding of genre that knows in engineering, technical and design effort is often in the service of decision making. Thus, genre constraints will only allow expression to meet those ends. While students recognized the rhetorical nature of genre, they struggled to come to terms with it.

Another presumption for students was that engineering and engineering writing are two different activities. That is, students did not see engineers as principally concerned with creating texts in order to direct decisions, but instead as designing artifacts. Silvio exemplified this position, questioning whether Professor Connolly even cared about the design. She, of course, did, but the presentation is an integrated set of mutually elaborated forms. The design is a good one in so far as the theory of operations, the calculations of the safety factors, and the make/buy decisions were sound. Students did not see the two efforts, designing and writing, as connected as they actually are. The connection had not be made for them that, as Dorothy Winsor notes, "engineering is knowledge about objects and how to build them rather than the actual building itself, [so] it is necessarily a symbol-bound field" (Winsor, 1990, p. 59).

Students had the same view of engineering writing as Bucciarelli’s (1994) engineers. Recall Bucciarelli’s characterization of documentation as an obituary for the design process and add Kathryn Henderson’s (1999) technical writer’s perspective of engineers prioritizing the “exciting design process” over the rhetorical work of manual
writing, and one may see how this attitude towards writing starts early in engineering education (Bucciarelli, 1994 p. 195; Henderson, 1999 p. 66). Bucciarelli’s and Henderson’s engineers’ denigration of writing failed to notice how their designing was thoroughly mediated through texts and writing texts. Winsor’s (1990) investigation of automotive engineers reveals that while the final product of engineering is (say) an engine, the knowledge and value of that engine is in the writing that unfolds it as an object meeting certain requirements and offering certain advantages. The engineering product and the texts about it are inextricably linked, and thus documentation is part of the design object, a point Bucciarelli (2002) later echoes.

Though students chafed under genre constraints, I do not want to give the impression that the presentations disallowed any and all personal expression. Students did realize that some requirements allowed a space for play, or as Steven in an interview put it, a way “to do us.” Students located opportunities in the presentation to present or perform the personality of their group. For instance, one group introduced each member of their group in the graphical style of the sitcom *It’s Always Sunny In Philadelphia’s* promotional materials. Another group played a video of their solar tracker design spinning 360 degrees to AC/DC’s “Thunderstruck.” The group I observed, SunTrac, broke down their group’s contributions by using historical personalities to illustrate their role: Bob was the Steve Jobs of the group, Steven the Walt Disney, Sedat David Ramsey, Benny Madeleine Albright, and so on. This creative excess was in addition to using other genre opportunities such as naming their group and conceiving of themselves as a start-up or an actual engineering firm.
Freedman (2008) calls on researchers to expand genre theory in order to recognize and attempt to account for data that’s is ill-fitting to contemporary ways of understanding professional communication and rhetoric, that is, the striving for conformity. Freedman notes instances where writers continue composing in excess of the social situation which the genre constructs. She cites a group of computer science students who continue to work on a coding project well after the work was turned in in pursuit of the “desire to achieve something beyond what was sufficient for the grade: elegance, neatness, simplicity, ‘personal style’” (p. 131). Freedman suggests that students understood their work in its transactional capacity, but also conceive of it as an artifact, an act of poesies, that can have aesthetic dimensions along with and perhaps in excess of transactional dimensions (c.f. Wickman, 2012). Students recognized these possibilities in the engineering presentation.

However, there is no evidence to suggest that their efforts to stylize their presentations compensated for other genre constraints. They traded one desire, the desire to foreground their design and its details, with the more immediately consequential desire for getting a good grade. Not one of the design presentations sacrificed the other generic forms (FMEA, Gantt chart, Pugh Chart etc.) in order to give their design (what they deemed) greater scope. Students did not put up resistance to the genre, but instead they suppressed their desires to display pride in their designs.

However, like Freedman’s computer science students, the students I talked to did see their design as artifacts as objects worthy of admiration and aesthetic appraisal. As Benny told me, “We wanted to show something new and we wanted to show something that actually works.” The design had a value and purpose beyond the social. The students
valued it as an object of craft knowledge, an object able to reveal care, nuance, labor, and to meet the standards for an engineering object.

**Engineering as Genre Knowledge:**

A rhetorical perspective on genre knowledge sees writing and communication generally as effecting change and persuading others to action. This kind of perspective is more fully made available to students once they have been socialized into an organization that is powered by typified responses to recurrent situations involving procedures and decisions, like an engineering firm. In the classroom, students may only attain a relational genre knowledge, because the duality of context, both school and work activity systems being operative, has them address work exigencies through school exigencies, but the full force of the work exigency is attenuated by being cut off from the organizational structure and motives of the workplace (Artemeva & Fox, 2010; Dannels, 2009). The tension between school and work may affect the student’s willingness to adopt fully the professor’s viewpoints on design, engineering, and generic forms, because the professor’s viewpoint is prospective, while the pride in their craft is an immediate relation in the students’ mind.

The conflict illustrated here suggests that, in the process of building generic knowledge, student feelings about the production and use of artifacts for generic purposes changes dramatically, and at some points can be at odds with professional demands. It also suggests that students have their own ideas about how what they build or design should be received and valued, and these kinds of perspectives are not valued by professional engineers or other professionals in industry, or at least not in the same way or all the time. This is not a trivial issue: As Dorothy Winsor has persuasively argued,
control over the form, content, and action of genres generates power, and power
determines what ideologies and mandates prevail inside an organization (Winsor, 2003.)
It is important to see that this power dynamic is instilled early in engineering education
and factors into the process of professionalization and building professional genre
knowledge.

One way to alleviate some of the tension students feel, would be to manage the
expectations of engineering through Rhetorical Genre Theory. Students need not read
Burke, Bitzer, or Bakhtin (though it would not hurt them), but they should know that
genre is a matter of enacting social intentions through available and expected forms, and
engineering is fundamentally a matter of social action performed through texts.
Designing and documentation are part of the same process, and one does not matter
without the other. A design is what it is for others through writing. Cluing students into
that fact would help them see engineering in its professional register, as a practice of
communicating ideas for creating useful artifacts. Such an attitude would be especially
helpful for students at the University where this study was undertaken, because the next
course, EMAE 360, in the design sequence focuses almost entirely on creating
documentation. Understanding how genre works would help students better establish
their purpose, context, and audience for their design work by understanding the kind of
practice EMAE 260 tries to mimic. As the work of Vinck (2003) and Trevelyan (2009)
demonstrate, engineers practice is thoroughly communicative, so a better understanding
of how to communicate is crucial for professionalizing students.

The final presentation does not just conclude EMAE 260, it closes the chiasmic
structure of the course. Through lectures and various texts students are taught to attend to
engineering like professional engineers. But the resulting focus and the strategies to maintain it become reassessed, negotiated, supplemented, and scrambled within the emergent social order of the group work as students attune themselves to designing. When students are then called on to present their work, they struggle to recontextualize their work through the expected genre, a genre structured by the professional attention demonstrated in the classroom. As a consequence. Students experience engineering as a split between the creative work of designing and the comparatively dry work of writing, and this perspective may persist into a student’s professional career.

What does this say about engineering education? It says that while the worry of professional education centers on whether skills from the educational domain will successfully translate to the professional domain, there is not enough notice paid to what unintended ideologies are transferring, such as reification of the separation between design and writing. Even Bucciarelli (1994; but see 2002) who insists that designing is a social rather than a technical process, fails to appreciate the work of writing. Other engineering educators, most prominently Leydens (2008; 2012; Paretti, McNair, & Leydens 2014,) see clearly the connection. Engineering communication used to be TPC’s purview, but the field has moved on. A search of titles in the flagship journal of the field, Technical Communication Quarterly, returned two articles focusing on engineering writing in the last decade (Taylor, 2011; Wolfe, 2009). The Journal of Business and Technical Communication has been more active in researching these connections, but interest has tailed off there as well. Symbolic analytics/workplace writing, digital rhetoric, global communication and many, many other interests have overtaken the
concern with the literacy and practice of young engineers and scientists (see Kynell & Tebeaux, 2009 for some discussion of the change).

This chapter and the dissertation as a whole calls for a rapprochement between technical communication and engineering education. This work is already underway within engineering education (see Paretti, McNair & Leydens, 2014 for an overview). Though TPC seeks to broaden its scope through diverse research pursuits, its traditional home in engineering communication continues to present important intellectual challenges. The ideas students have about engineering, its goals, its methods, its practice, and its ethics are shaped in courses like EMAE 260. A rhetorical understanding of writing and communication may lead to a better understanding of genres as responsive performances rather than display windows of effort. Furthermore, students could be shown that in large part, the foundation of engineering practice is engineering writing as much as it is science, mathematics, and technology. Further research is called for to explore how writing can be integrated into the very heart of engineering education (see examples in Artemeva, 2009; Ford, 2012).

The reductive process of genre composition is a more complex and weighty matter than at first glance. Such a common phenomenon—students having to realize that design presentations are not received like things they did in high school shop class or in Lego competitions or even when they were learning the CAD software—seems beneath critical engagement. But student feelings and motives for design and genre work reveal other motives suppressed or transformed by disciplinary education, and point us to other issues with how writing in a discipline is conceived. By recovering these ways of understanding design and engineering and the reasons for understanding them that way, teachers may
invent new strategies to articulate the stakes of professional genre composition to engineering students and perhaps cultivate in them craft pride in genre composition itself.
Chapter 6: Conclusion

The dissertation began by translating the work of EMAE 260 into an effort to teach engineering students how to attend to engineering like professional engineers. Attention is a manner of selecting relevant actions for a task, and in defining attention in this way, a spotlight was cast on the ways EMAE 260 sought to direct and structure how engineering students went about designing. Using “attention” as a heuristic helps researchers get into the mundane, embodied actions that constitute practice, how they are taught, how they are implemented, and how they are exercised. Attending to attention shows that what falls through the cracks of analysis at higher levels of activity matters to the way routine practice is carried out. The dissertation rested on an equivalence between attending to and learning to do engineering by understanding the course’s efforts to have students work through constraints as attending to how professional engineering is executed. This direction and structuring of attention was accomplished by the professor, textbook, and course materials by showing students not only what to attend to, but how. EMAE 260 sought to order students’ attention to design to accord with professional engineering practice that concerned itself with not only the technical specifications of the artifact, but the many sociotechnical relationships that condition the final product.

EMAE 260 used a variety of demonstrations in lectures, a stage gate design process, genres, texts, quizzes, and homework to direct, structure, and calibrate student attention to engineering. EMAE 260 supplied students with a field of constraints which they had to learn and account for in their designing. The stage-gate design process and its instantiation in genres such as the Gantt chart motivated students to set incremental goals and apply particular methods and strategies to meet those goals. The strategies and methods such as brainstorming and the Pugh Method provided students procedures to
direct invention and judgment in order to produce a design that spoke to the concerns professional engineers possess. Presentations displayed this attention to professional engineering, consisting as they did of a genre set that put forth the constraints students designed under, the technical information they calculated, and their proficiency with CAD. Within groups, students talked, gestured, sketched, and searched the internet to bring forth configurations of relevant constraints in order to calibrate the group’s attention to the design. Coordinating attention was integral to design work because the design project needed every member’s input.

Students followed the course structure for designing, but found implementing some of the strategies and methods for group work difficult. They also chafed under the genre constraints of the presentation, wishing more space and time be given to their design. In the case of inventing the design, students gave themselves free reign to present ideas and elaborated them according to how they well sparked the collective group interests and how they satisfied the requirements of the design. Opportunities to apply brainstorming methods were quickly abandoned because the dynamics of the groups’ social order (characterized by turn-taking in conversation, the flow of conversational topics, generation of ideas, and the snap judgments that followed), could not accommodate them. In making decisions, the process was often weighed down by debates over the values of the group members, so decision methods that did not include the determination of values were similarly weighed down. Students were able to meet genre expectations, but they did not exhibit genre knowledge, failing to understand the design artifact as enmeshed in a genre set through which it can communicate its value.
other words, attentional structures and resources from the classroom did not wholly transmit to students for reasons cited above.

This problem with transmission highlighted an issue not often accounted for in investigations into socialization and professionalization, namely the implementation outside of the classroom of what is demonstrated inside the classroom. I posited in the second chapter, that students lacked the kind of instruction to successfully integrate professional engineering attention into their designing. They did not have the skills to contextualize the strategies and methods from the classroom into their group work.

Further analysis revealed that students had to implement several rhetorical skills such as framing, judging, and genre writing, which for one reason or another had not been a focus of or had not been emphasized enough by the course. What appears through analysis are two main foci for TPC, engineering education, and design teachers to improve the professionalization of student engineers.

The first is to notice the rhetorical nature of framing, judging, and writing in engineering design and gear instruction towards those goals. In both framing and judging, representations played a large part in calibrating joint attention and providing material for reflection. Pushing students to consider the best representational strategies gives them a better chance to order and clarify their design activity. As discussed in detail the end of the last chapter, providing students with a frank discussion of the stakes of engineering communication in relation to the design artifact and genres help them to see 1) the sociotechnical reality of engineering and 2) the way writing is integral to what a product, process, or system is and can be. Genre knowledge clues students into attending to engineering like professional engineers by understanding the actions engineers have to
take and through what means. Helping students see engineering as inextricable from communicating about engineering promotes uptake of how professional engineering operates.

The second focus concerns helping students attune their group work to enact the strategies and methods of engineering design practice. As I detailed in the second chapter, students do not have the necessary underlying skills to apply the attentional structures of the classroom, nor do they monitor their group activity well enough to follow the rules of concept generation formulas. I suggested the idea of coaching students through the design process so their designing can take advantage of the best practices available. My idea of coaching is inspired by Bean’s (2011) Engaging Ideas, where he touts small group work as a way to teach students disciplinary reasoning. I believe one can go a step further and promote a notion of coaching that puts the design ‘expert’ in a position to guide ‘novice’s’ design practice.

Thinking towards a model of coaching for design, I pull from my experience teaching a professional writing class where because of the class size, there was only one group of students, so I could take time to focus on where they were on their projects. I asked students to use class time for group meetings to discuss their approach to upcoming issues as they designed a website for the University writing center. On days when they had group meetings in class, I would ask for an informal progress report, and I would offer them my advice or point them towards a strategy for dealing with a particular issue. For instance, when they were looking to generate web design ideas, I suggested they look at certain University writing centers’ web pages to get a feel for the range of web design options. When they were trying to set an agenda, I encouraged them to use the
blackboard and projector. When they were attempting to portion responsibility I took the opportunity to discuss team charters

In observing the SunTrac group, I often had to check the impulse to suggest to students better ways of designing. Though I was no expert, I had gone through the course once already in a pilot study, so I was well-versed in the best courses of action in each design stage and knew what Dr. Connolly expected. Because I was an observer and did not want to take up the role of instructor, I mostly kept quiet, excepting one or two suggestions. However, I saw the potential for an instructor to act as a type of coach; someone who was not necessarily there to design, but not quite a type of figure stashed within the group to ensure students were following teacher’s directions. Instead, a coach that could offer pointers to how designers approached problems. For instance, students could have saved some time not working on the wrong formula for wind force. Someone with a bit of knowledge could have easily clued them into what they were doing was a dead end. At certain points in the semester, students could have used reminding of a point made by Dr. Connolly or repay a chapter in the textbook with a second look. Some might worry that students should be making mistakes on their own, and that is true, but coaching does not prevent mistakes: coaching simply puts available ways to succeed before the students, allowing them the responsibility of enacting success.

There is precedent for coaching in engineering education (Manuel, Mckena, & Olson, 2008) and design pedagogy (Schön, 1987) that may act as guides for an effective model for coaching. Additionally, case studies may offer avenues for dealing with the staffing and logistical issues inherent in such a paradigm shift to a coaching model. But the issue of attunement identified in this dissertation suggest that professionalization
requires a more intimate approach and a focus on the ways design is organized and structured *in situ*.
Appendix 1

Extended Transcripts:

Appended here are transcripts from the scenes from chapters 3 and 4. In order to provide context, I have provided transcription from roughly 15 seconds before and roughly 15 seconds after each excerpt. I say ‘roughly’ because in few a scenes, cutting off the transcription at exactly 15 seconds would have marred the sense of what was said.  

**Transcript 3.1**

[Group searches for whiteboard makers that are not to be found]

Silvio- So, um, I'm just going to present my design, um, so we all kinda decided that we wanted some kind of um either it was going to be a pole or stand that rotates at the base, at least thats so far what the designs are. Um, my design would be kinda, it'd be a tripod kind of thing *(fingers tips of each hand touch to form for a triangular shape)* and then in the middle there is a bar across *(gestures a bar across in the space where he had formed a triangle)* so it's like a triangle, [like a teepee]

Pranav- Yeah]

Silvio- *[inaudible]* And then on the other side there is a bar across it *(makes bar motion again)* And there's a wheel *(makes a circle with fingers of both hands, looking down at sketch book)* and the solar panel's attached to one side of it *(right hand makes vertical motion up and down)* [suppresses a cough]

Silvio- *(Looking down at sketch book)* And then underneath that wheel, you could have a little cupped metal piece with treads on it *(cups hands open up towards the ceiling, and then uses right fingers to touch off “treads” on the remaining cupped left hand)* so you either move this part *(starts to move cupped hands to the right)*(.) or actually you would have a flat piece *(flattens left hand)* and you would push that this way *(pushes flat piece to the right)* and that would actually rotate the wheel *(makes hand gesture for wheel, and rotates it to the right)* and that would have the solar panel on it *(puts right hand flat to the right of approximately where he just had gestured the wheel)*, um. And that way you wouldn't actually have a motor turning that wheel you'd just get the track moving *(hands down underneath the table)*. Um=

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22 The transcription conventions are adapted from Wood and Kroger (2000). “[Lines]” designate overlapping talk; “=” latching of utterances; “(.)” noticeable short pause; “*(Bolded Brackets)*” description of gesture; “[†]” transcriber’s comment; “((double parentheses))” transcribers description of off camera action; “ro:wing” indicates an elongation of a syllable or sound.
Pranav- Kinda like a ball and socket joint?

Silvio- Yeah, kinda of. So that's kinda how my idea was. You wanna explain yours, Benny? (pushes sketch pad towards Benny)
(Benny stops writing and takes sketch pad)

Benny- So there is one pole, one pole (.)(makes quick vertical motion with one hand) and there is a magnet that [inaudible] spins the pole at the base (points with pencil to sketch) the pole is standing on, if it makes sense (holds up pad to group)

Silvio: hmm

Transcript 3.2:

Sedat- You know that little animation?

Pranav- Yeah

Sedat- Where did you find that? (scrolling a Google Image page of gears)

Nico- You mean that (Nico turns his computer towards Sedat)

Sedat- Yeah that thing, so maybe instead of a cable that would be exposed we have that in a gear box (points to Nico's open computer displaying an image of a worm gear)

Pranav- (Looking at Sedat) Yeah [inaudible]

Sedat- (Puts one hand above the other to make a box) And then we have an extension (right hand cupped moving up and down as if gripping the length of a pole)(.) out of it (points to worm gear) that pushes it out (right hand moves up in pushing motion) and then the same vertical will be(.) (he puts hands up, palms facing each other about 20 inches apart) and then you have two supports and the, like, you take one motor(.) then you have two on each end (hands turn downward as if preparing to play a chest-high piano, then hands turn over and fingers are made vertical again, palms facing upward) and then you'll be pushing it [inaudible]= (right hand moves up, left hand moves down simultaneously)

Steven- =See also with that, like you could generate-so if you turn (puts hands up to mimic Sedat's spacing) so if you turn one motor on and turn the other one off so it pushes one up and pushes the other down (the left hand goes up and the right hand goes down, creating a mirror image of what Sedat just performed) you could possibly turn the other motor (points to Sedat) and maybe generate [inaudible] 'cause then you'd be (right hand goes up, index finger gets pointed out, finger drops slowly)(.3) I don’t know (makes a beat gesture), I don’t know if that would actually work with that but (pauses a beat, then resumes the pointing gesture that drops slowly)(1.0) but
(drops iconic gesture, goes back to beat gesture) but it would be saving energy to turn one off and push the other one up.

Pranav- I know what you mean, like a cable car system=

Steven- =Yeah

[Pause of 4 seconds]

Sivio- Kinda feel like were fixing this idea a little

Pranav- it's interesting, yeah.
[smiles and murmurs from the group]

Nico- So (turns the lab top towards the group) like [inaudible] jack with the worm gear idea[...]

Transcript 3.3:

Steven. Um (. ) Steel cables we already decided

Bob- what if we do this, what if we do this
(erases lines on the sketch pad. Crosses out one of the choices of solar panel.)[

Sedat- But also-[  

Bob- What] if we do (. ) imagine- a pole coming out (starts to draws pole at right angle from previously sketched shaft) pole there, pole there (draws poles at two points on the paper) and the pole came out like that too (draws a pole that extends out to the viewer). Um, chains go [indistinct] (draws line connecting to the poles) (1.0) And this is ro:tated (makes semi-circle underneath shaft) and this is dragged along like this (traces chain).

((Silence for a moment. A couple of muffled questions are asked off screen))

Steven- Are they gonna be like a triangle kind of shape, (makes a triangle with his hands) So like one's over here and another's over here (he points to two points on the triangles and moves his hands down to frame the table top in with fingers shaping a triangle in front of him) and coming out like 120 degrees?

Bob- Imagine, imagine a pirate ship.

Pranav- Ok
Bob- So you know they- the workers pushing the thing around the things (makes a sweeping oar motion with both arms, two times)?

Pranav- Right

Bob- That’s what I am imagining (makes circle motion with one hand, as if he's stirring something)

Steven- Oh, ok

[a 3 second pause]

Steve- Is it like (.)( traces quickly with hands in front of him Bob's gesture) ok.

Bob- So how do we powr something liek if if it's attached like thus so it rotates as well (uses pencil to trace his sketch as he asks the question)

(a 7 second pause)

Transcript 4:

Nico- (looking at whiteboard) That’s acting on the [entire

Pranav- (holds up right hand) For] a hundred mile per hour wind with panels like this (.)(uses left hand to audibly smack the open palm of the right hand) you’re going to get nine pounds of force.

Silvio- Right.

Pranav- That actually makes sense, right?

Silvio- No:. If you think of a hundred mile an hour wind acting on, what is it, what is it, 72.2 square feet of solid surface and it’s just nine pounds of force? That doesn’t seem even remotely possible.

Steve- wait should I square (points the board)

Nico- 72.2 feet squared! That’s huge.

Steve- (quietly) Is it in inches, is it inches?

Bob- (points to equation for calculating area of solar panel) Someone multiply this again.
Appendix 2

Table of Data Collection:

Table A: Data Collected from EMAE 260.

<table>
<thead>
<tr>
<th>EMAE 26: Design and Manufacturing Methods I</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ethnographic Observations and Field Notes.</td>
</tr>
<tr>
<td>In Fall 2014, I observed 80% of EMAE 260’s class meetings, which were 50-minutes long, except the week of final presentations which ranged close to two hours a session.</td>
</tr>
<tr>
<td>2. Interviews:</td>
</tr>
<tr>
<td>I conducted interviews with 10 students and the course instructor (6 of the 10 students were also from the group I observed, while the 4 other volunteers were from different groups). These interviews lasted 45 minutes on average, though the interview with Professor Connolly lasted nearly 90 minutes.</td>
</tr>
<tr>
<td>3. Textual Materials:</td>
</tr>
<tr>
<td>I collected the following texts: (1) the syllabus and weekly schedule; (2) the course textbook; (3) all of the groups’ final presentations; (4) PowerPoint slides of the lectures.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Undergraduate Engineering Design Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ethnographic Observations:</td>
</tr>
<tr>
<td>During the Fall of 2014, I video-recorded on a digital camcorder students’ design meetings at various locations across campus for 14 weeks. I attended 80% of the group’s meetings, which averaged 2 hours per meeting. This added up to approximately 21 hours of video.</td>
</tr>
<tr>
<td>2. Textual and Digital Materials:</td>
</tr>
<tr>
<td>I was given access to the group’s Google Drive where drafts of ideas, presentations, photographs, and CAD drawings were stored.</td>
</tr>
</tbody>
</table>
Appendix 3

Interview Questions:

EMAE 260 Instructor Interview Questions:

1. What do you see as the aims and goals of EMAE 260?

2. What do you hope students get out of EMAE 260?

3. What role does EMAE 260 play in the education of engineering students?

4. What role does the design process play in professional engineering practice in the world?

5. What role does the design process play in EMAE 260?

6. How do you prepare and present the class material?

7. How do you think students learn in EMAE 260? What methods do you think they use? (Follow up Questions)
   - What role do lectures play?
   - What role do the small groups play?
   - How do you train the TAs to grade work?
   - What role does the design software play?
   - What role does the documentation process play?
   - What role does brainstorming play?
   - What role does the textbook play?
   - What roles do the homework and tests play?
   - What role do the final presentations play?
What role do you see the Q&A section playing at the end of each presentation?

What role does the bound document folder play?

8. What do you want or look for from student presentations?

9. What do you want or look for in final designs?

10. What is the relationship between the design process you present to students and the design process you undertake in industry?

11. How is the design process in EMAE 260 different from the design process in industry?

12. As far as you know, how does the design process vary in different engineering fields?

13. What helped you learn to become an engineer?

EMAE 260 Student Interview Questions

1. What year of school are you in?

2. Have you participated in an internship or co-op?

3. Tell me why you chose to study in your engineering field?

4. What do you plan to do after your undergraduate career?

5. What do you see as the aims and goals of EMAE 260?

6. What role do you see EMAE 260 playing in your undergraduate career?

7. Do you see EMAE 260 preparing you for professional engineering?
8. What do you see as the aims and goals of the class lectures and other course materials?

9. What do you hope to get out of EMAE 260?

10. What are the aims and goals of your group?

11. Which components of the design process does your group prioritize?

12. How are group decisions about the design process and group members’ responsibilities made?

13. Where does your group work and why?

14. What is the relationship between your group activity in designing a product and the way the design process is presented in class?

15. What are the tools (email, SolidWorks, Windchill, Google Docs, library resources, sketches, drawings, etc.) you use to complete the design process and why?

16. What are the aims and goals of the final design presentation?
Bibliography


Geisler, C., & Lewis, B. (2007). Remaking the world through talk and text: What we should learn from how engineers use language to design. In R. Horowitz


*CoDesign, 5*(1), 65-76.


