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DISCOURSE ANALYSIS FOR DESIGN EDUCATION

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Abstract

Engineering has its own unique, identifying culture that arises from the values, attitudes and beliefs that are promoted within it. As this culture is initially learned in engineering programs, curricular development requires an understanding of the current culture and what the new culture should be. In an era where increasing emphasis is being placed on the teaching of design within engineering, the implied curricular changes require an understanding of what the current culture presumes. To better understand this culture, a discourse analysis was carried out using engineering design textbooks (written material) and student interviews (spoken material). The analysis of the written material indicates that the discourse portrays engineering design as logical, rational, clear, or, in other words, as close as possible to the scientific paradigm. There is also a strong link suggested between the ability to draw and the ability to design. The spoken material shows that some students make a strong connection between "picture" and design. There was also some indication that students had unresolved issues between the formality of engineering design and the freedom of creation.

Keywords: design education, discourse analysis, case study

1. Introduction

The 2002-2003 academic year in the Faculty of Engineering at the University of Calgary, Canada, marks the inauguration of the new "Design and Communications" courses, which are now compulsory for all first-year engineering students. One of the objectives of the course is to create a cultural shift within the engineering program by focusing on a more holistic model of engineering design. Unlike traditional engineering courses wherein students are expected to learn material in a lecture-based format, the new courses are being delivered in a laboratory environment, akin to design studios. The aim of these design labs is to provide students the opportunity to engage in inquiry-based learning in the context of engineering design. Rather than being provided with idealized problems and "perfect" solutions, they are encouraged to develop their own problem statements, explore a range of potential solutions and navigate through the hurdles that may arise in the process. These hurdles may be either technical or non-technical in nature and students are expected to address both in a thoughtful manner to produce an integrated design solution.

2. Objective

The organizers and instructors of the "Design and Communications" courses face a formidable task. Not only are the courses new and the teaching style non-traditional, the majority of the 600+ students are new to the university. As foundational courses for the engineering program, they have the potential to have a significant impact on the development of students' understanding of engineering and how they will engage in their profession upon graduation. The beliefs, values and attitudes acquired by these departing students depends, to a large extent, on the culture that exists within the engineering program. Hence, any effort to bring about a cultural shift assumes an understanding of what the current culture is (and how it was created) and what the new culture will look like (and how it might be achieved). Thus, as the first step of this on-going study, the main objective is aimed at understanding the "old" culture of engineering and engineering design.

3. Methodology

The basic methodological framework of this study is a combination of case study research and discourse analysis.

3.1 Case study research

Case study research is empirical and seeks to understand phenomena via contemporary events in real-life context [1]. As case studies are analysed on a holistic level, the boundaries between the phenomenon under investigation and the context are ill-defined. Typically, this type of research relies on multiple sources of evidence to study the phenomenon. These sources can be written (archival) or spoken material, or may take the form of an object.

Case studies can be classified as exploratory, descriptive or explanatory [1]. The type of study depends on the questions one is asking (who, what, when, where, why, how), extent of control one has on the situation and whether one is studying contemporary or historical issues. For instance, when studying historical issues, one has no control over behavioural events, as the past is dead. For contemporary studies, one has no control over current events. This particular study of engineering design is part descriptive, as it seeks to understand *what* the current culture is, and part exploratory, as it hopes to find *how* the culture is brought about and maintained.

3.2 Discourse analysis

Discourse analysis considers language to be the fundamental means by which ideologies are transmitted, enacted and reproduced within society [2]. It looks for patterns of how language is used in a particular tradition or field of study thus exposing hidden ideologies. By constant exposure to discourse over periods of time, people begin to view "manipulative strategies" as natural, neutral or common sense. Thus, society not only shapes discourse, but is shaped by it.

A particular type of discourse analysis is known as critical discourse analysis. This approach looks at how dominance is maintained in society through the use of spoken and written language [3]. It is aimed at better understanding social issues by looking at the patterns of language used by dominant groups to maintain a social order that is in the interest of the dominant groups but result in inequality, injustice and abuse. Thus, racism, sexism, classism, etc., are present in these discourses but concealed in terms that make the argument seem reasonable.

The discourses of the dominant groups are often presented in an "us-them" argument, with the "us" being presented in a positive light and the "them" in a negative one. There are six ways in which this might be accomplished: argumentation (the 'facts'); rhetorical figures (e.g., hyperbole, euphemism, metaphor); lexical style (word choice); storytelling (personal experience); structural emphasis; and quoting credible witnesses [3]. With these moves the speaker/writer 'rationally' defends his or her position.

It is important to note that in conducting discourse analysis, one does not do so from a "neutral" stance. Indeed, assuming a 'neutral' stance renders one's analysis invalid. One must take a position. Furthermore, the aim of the exercise is to bring about a change to the discourse patterns in an effort to effect a corresponding change in society, creating greater equality within it. Critical discourse analysis is therefore normative.

At first glance, the intent of critical discourse analysis, to expose the rationalization of dominance of one group of people over another, may appear to be inappropriate for the study of discourse within engineering design. However, engineering, too, has dominant discourses which emerge from the spoken and written material of engineering and engineering design. These discourses can often be framed within the 'us-them' argument. The 'us' can be the 'preferred' view of engineering design and the 'them', the "inadequate' view of engineering design, such as non-engineers or engineers not involved in significant amounts of design activity.

3.3 Data sources

Discourse/case study data is drawn from both written and oral materials. The written materials consist of resources that engineering students are likely to read as part of their education in design. This limits the selection to textbooks and similar materials. Some material from the Design and Communications course website are also examined in the study. Journal articles are not reviewed as it is not expected to be a likely resource of engineering students. The spoken material comes from interviews conducted with fourth-year engineering students early in 2000. These students had not taken the Design and Communications courses and hence can be seen as "representatives" of the "old" culture. However, they were taking a relatively new fourth-year design course at the time of the interviews and, as such, may be interpreted as constituting a "transition" somewhere between the more traditional engineering culture and the new culture the Design and Communications courses are trying to create.

3.4 Analysis

The analysis consists of first creating a sketch of the broad characterizations of the discourse by examining both the written and spoken material. The next step is to go through the layers and uncover some of the deeper ideological meaning within the discourses. Meanings become clearer as patterns of language use emerge [2]

It should also be noted that the analysis is not based on huge volumes of text and spoken material. Rather, as is normally the case with case study research, a limited number of key phrases are selected from the data sources which provide illustrative examples of some styles of discourse on engineering design. As instances, context is highly important and we therefore do not purport to make any “universal” statements about the culture of engineering design.

4. Discussion of discourses: text

Much of the discourse found in the texts depicts engineering design as a rational process. Although such a “conclusion” before the analysis section might seem out of place according to the traditional rules of engineering argument, placing it before the analysis is in keeping with discourse analysis as it makes our perspective or bias clear from the outset. Equipped with such knowledge beforehand, the reader, we believe, will be better able to understand the development of the discourse analysis itself.

4.1 Historical beginnings to rationality

Some of the texts begin their discussion of design with a very brief discussion of the history of design. Luzadder and Duff [4], for example, state that “For almost twenty thousand years a drawing has been the main way that ideas have been communicated.... One of the earliest drawings, found in Mesopotamia, shows the use of a wheel about 3200 B.C.... Another example of early drawing is a floor plan of a fortress made on a clay tablet around 4000 B.C.” (p. 3). Jensen and Helsel [5] follow this pattern on two occasions. The first occurs in their introductory chapter on drawing: “Since earliest times, people have used drawings to communicate and record ideas so that they would not be forgotten” (p. 2). The second occurs in their chapter on design: “The history of civilization is the story of the unique ability of men and women to utilize intelligence, imagination and curiosity in the creation of tools and artifacts that ease the burden of physical labor.... The combined efforts of scientists, engineers, technicians, and skilled tradespersons have been largely responsible for the high living standards presently enjoyed by western civilization” (p. 432). Ullman [6] begins his book by stating that “Beginning with a simple potter’s wheel and evolving to complex consumer products and transportation systems, humans have been designing mechanical objects for nearly 5000 years” (p. 3).

The language used here posits design as a basic human activity, perhaps a natural one. Design is fundamental to civilization. The connection to civilization is important as it points to a recurring theme within engineering, namely that of *progress*. To be civilized is a “higher” state of being than to be primitive or savage. When [5] refers to the “high living standard presently enjoyed”, the “high” implies an upward movement, and the desirableness of this high standard is reinforced by “enjoyed”. “Presently” implies that these good conditions did not exist previously, and “standard” tells us that these conditions are likely to be enjoyed for some time. Ullman speaks of going from the “simple” to the “complex” by “evolving”. “Simple:” might be interpreted as “primitive” or “savage” and “complex” speaks of some kind of advancement. “Evolving” evokes a Darwinian or natural progression from the simple to the complex and, by extension, places the contemporary designing engineer (read: “us”), who designs complex products, at the top of the heap.

4.2 The metaphor of language

The metaphor of language commonly occurs in the texts for various purposes. Consider a statement from [5]: “Drafting, therefore, is a graphic language, because it uses pictures to communicate thought and ideas” (p. 2). As drawings are used to “communicate”, it should therefore be deemed a language. Language is also a feature of the “civilized” human.

Drawing shifts to "drafting" and now the stage is set for the entrance of the designing engineer. They go on to say that "Even highly developed word languages are inadequate for describing the size, shape, and relationship of physical objects" (p. 2). Engineering drawing is now elevated to a very high status, for even languages which are "highly developed" are "inadequate". It would appear that to be good at drawing or drafting is a sign of extremely high development.

Luzadder and Duff [4] also use the language metaphor. Within the first paragraph, they state that it is "*natural* for humans to graphically draw their ideas" (p. 3, emphasis ours). If drawing is "natural", then it stands to reason that engineering design, too, is natural and works with nature, rather than against it. They then develop the connection between drawing and design by stating that "drawing came to be ... a means of showing design concepts...." (p. 3). The connection to language quickly follows: "Engineers, drafters, and other members of the design team must work closely on the design project and speak the same language: *the language of engineering drawing*" (p. 5, emphasis theirs). The connection to language and drawing is further reinforced, as "engineering drawing is a *graphic language*" (p. 6, emphasis theirs) and a "design engineer ... must be able to *read* and understand all aspects of the drawing" (p. 5, emphasis ours). They extend the metaphor further, using it to explain how the text itself is organized: "The purpose of this text is to present the *grammar and composition* of engineering drawing, much as an English text presents the grammar and composition of our written language" (p. 10, emphasis theirs). They also use the language metaphor with respect to the importance and limitations of sketching as a means of engineering design: "*Just as learning the mechanics of English does not make one a creative writer, so will training in sketching not make one a creative designer*" (p. 59, emphasis theirs). Just what "learning the mechanics of English" would allow one to do in terms of language is unclear. Presumably, they refer to the ability to understand grammar and spell according to convention. It is also unclear whether design is a metaphor for language or language a metaphor for design.

4.3 Clarity/ambiguity

One of the special features of this engineering "drawing" is the clarity it affords its readers. Jensen and Helsel [5] state that "for every manufactured object there are drawings that describe its physical shape *completely* and *accurately*.... Drafters ... describe *exactly* what materials workers are to use on a particular job" (p. 2, emphasis ours). It is also mentioned [4] that "drawing must conform to *exacting standards* for their preparation and understanding" (p. 5, emphasis theirs). Furthermore, "engineering drawing *teaches* the principles of *accuracy* and *clarity* in presenting the information necessary to produce products" (p. 9, emphasis ours). Drawing is not only a skill, but it instills certain (desirable) values.

The assumption of clarity extends beyond the drawing/drafting domain of engineering design. According to [5], "a *clear* definition of product requirements leads directly to choice of the construction material" (p. 433, emphasis ours). Ullman [6] states that "in order to know how well the function is fulfilled, we must develop *clear* performance measure for it" and, later, "we must start with a *clear* need" (p. 21, emphasis ours).

One can't help but wonder if the language metaphor might have been taken a little further. An important feature of language is that it is often *ambiguous*. It would seem that ambiguity would be a worthwhile concept to pursue in design, for many things in design are quite unclear, such as the exact nature of the problem and the validity of the proposed solution. The language metaphor would show clarity to be an elusive goal. The insistence on clarity with the accompanying aversion to ambiguity is presumably a defence against the potential loss of stature of the profession as a lack of clarity might begin to nibble away at the assumed foundation of rationality. Uncertainty is a sign of weakness.

Some passages do indicate a recognition of ambiguity and a lack of clarity in design. Ullman [6], for instance, talks about the "ill-defined" problem or need on numerous occasions and mentions that he prefers to use the word "component" because "part" is "easily confused" (p. 18). The Student Manual for the Design and Communications courses [7] at the University of Calgary lists "sketching" as one of the "Visual Communication Core Competencies". Unlike "drafting", "sketching" connotes neither clarity nor accuracy. Under the section entitled "Written Communication Core Competencies", however, "concise, clear and accurate content" (p. 6) is listed as one of the skills of report writing.

4.4 Science

In both the first and final chapters of his book, Childs [8] describes some of the qualities of a designing engineer: "Allied to a knowledge of materials and existing technology is the general requirement for engineers to know what is technically and *scientifically* feasible so that '*far-fetched*' ideas can be *objectively* ruled out" (p. 7, emphasis ours) and "The qualities demanded of designers included detailed *scientific* knowledge, *logical* thought process, creative, conceptual and innovative abilities and communication skills. Traditional engineering *science* courses such as thermodynamics, heat transfer and fluid mechanics, statics and dynamics, satisfy the demands for detailed technical *scientific* knowledge and development of *logical* thought process.... This is of course aided by a good general knowledge of what has been done, what is possible and what is *scientifically* feasible" (p. 168, emphasis ours).

The juxtaposition of "far-fetched" and "scientific" indicates how important Childs considers science to be in engineering design. Although he puts "far-fetched" within single quotes in his text, it does nevertheless show that he at least partially accepts the idea that to be unscientific is best avoided. Science also leads to "logical thought". One is left wondering if there are many possible logical thought processes, or merely one, or if one can have a logical thought process that is not scientific. Although he does mention other qualities of an engineer that may be taken as non-scientific (unscientific?), such as "creative, conceptual and innovative abilities", science and the logic it engenders appear to be the home base (they appear first on the list). One may wander out from time to time, but should not stay away for too long. All engineering design endeavours eventually require the consenting nod of science.

The other word that stands out is "objectively". This would perhaps refer to the ability to look at things the way all or most other (competent) engineers look at things, based on the logical thought process(es) that come from science. On other occasions, there appears to be some compromise on the "objective" ideal, for we want the "best or most acceptable compromise between the desired criteria" (p. 5). If a solution is "acceptable" rather than "best", how does that speak of our objectivity?

Ullman [6] spends a good deal of time talking about the "ill-defined problem". A design problem is "ill-defined in that the problem statement does not have all the information needed to find the solution" (p. 7). He goes on to mention that there are many potential solutions and no correct answer. We can once again contrast this to Jensen and Helsel, who state that "A clear definition of product requirements leads *directly* to choice of the construction material" (p. 433, emphasis ours). Here, the reason that clarity is important becomes clearer: clarity seems to facilitate convergent (read: "logical") thinking. Engineers can only be logical in a sea of clarity.

The Student Manual for the Design and Communications courses [7] also attempts to address the issue. It reads: "The pursuit of skill development in creative problem solving requires a learning environment that is substantially different from the traditional mathematical/engineering format" (p. 7). What is different is that students no longer strive for the correct answer, but have to justify their design decisions. However, limits are imposed on the "creative problem solving" as "students are expected to manage their progress with a high degree of independence and *creativity* while maintaining an *orderly* record and description of their solution path" (p. 8, emphasis ours).

4.5 Economics

The texts reviewed for this study made innumerable references to the economic issues of engineering design. A prime example is Jensen and Helsel [5]. In their chapter entitled "Design Concepts", they state that the "purpose of any design department is to create a product which not only will function efficiently, but also will be a financial success" (p. 432). This belief in the importance of the "financial success" is continuously reinforced throughout the chapter, couched in words such as "cost", "costly", "cheapest". "expensive", "economics", "savings", "capital expenditure" and "right price". This is particularly evident on page 435, where the word "cost" or "costs" appears 24 times. We can contrast the emphasis on economic issues with those of safety. We found two references to safety in the chapter, one commenting on the potential hazard of a protruding setscrew on a rotating part, and the other spoke of the protection from sharp edges afforded by crown nuts.

The emphasis on economic issues demonstrates that engineers are active members of the dominant culture of their society, namely that of capitalism. Hence, engineers are not radicals and their work is not disruptive. Indeed, their work upholds and supports society, for it comes from it. Furthermore, a fundamental feature of this economic system is competition. Competition within the marketplace is seen as healthy as it is perceived to lead to an ever-improving, affordable product. Engineers are therefore constantly vigilant and on the cutting edge in their respective fields.

4.6 Need

When design is presented as an activity proceeding through a series of steps, the concept of "need" figures prominently in this framework. Occasionally, the idea of "need" is framed differently. For instance, Ullman [6] speaks of being "confronted by a need or desire" (p. 6). Subsequent references to this idea tended to coalesce to just "need", where allusions to desire seem to wane. For instance, he states that "a machine that ... has the capabilities to meet some need that is not fully defined" (p. 8) and, in his chapter summary, "establish need" (p.15).

Why would engineers prefer the word "need" over "desire"? "Desire" connotes the affective, emotive sides of humans. It speaks of irrationality. It conjures up design requests that are dubious at best. Desire can be overly interested in the self, fleeting and indulgent (and therefore potentially harmful to oneself). "Need", on the other hand, appeals to the cognitive, rational side of humans. "Need" can imply a sense of urgency, demanding of our attention, for to ignore a "need" is to shirk one's ethical duty. Need, unlike desire, speaks of some kind of value-neutrality, or at least values that are accepted almost anywhere. As such, it requires no ethical analysis and can be readily accepted as a given.

5. Discussion of discourses: student interviews

The spoken data comes from 3 fourth-year engineering students, Bill, Rob and Jane (all names are pseudonyms). At the time of the interviews, they were approximately halfway through the second semester of a two-semester design course.

The discourse analysis of interview data is much more difficult than that of written text. The speech is not arranged under descriptive headings, sentences are often incomplete and "tangents" are common-place. What is said is spontaneous, rather than rehearsed. In responding to questions, participants may give the answer they think is expected rather than answering according to what they actually believe. As students, they also lack the vocabulary typically found in many engineering design texts. Nevertheless, discourse analysis is helpful, if not necessary, to understand the engineering culture that has been engendered in the students.

5.1 Design

When asked for his concept of design, Bill said: "I suppose design would be starting with a concept and show how getting to like a.... I think of design as an actual picture, you know like a draft of what you're going to be doing. And then the third step would be to actually have the product." Design becomes engineering design "when you start to introduce engineering concepts.... But, in engineering design ... I think there's a larger space between the concept and picture". These engineering concepts would include "like material properties". Bill's idea of engineering design resembles a method with its three "steps" of "concept", "picture" and "product". An example of "concept", the first step, would appear to be that materials have properties. In this way, he alludes to the importance of science within the design frame. It is with these "concepts" that a designer is able to form a "picture". The notion of "picture" seems to be akin to engineering drawing or drafting. He thus makes the drawing-design connection. He makes no statements concerning creativity or imagination. He does state, however, that working at companies is "like the design course, you can go in any direction." He also concedes, "My answer has to be right. I need the answer." Bill appears to be caught within a clash of cultures: on one hand, from the new culture, he enjoys being able "to go in any direction"; on the other hand, from the old culture, he needs "the right" answer. He finds himself being pulled back to a sense of correctness, to a single answer.

Rob appears to believe in distinct differences between designers and non-designers. "Functionally, I think differently. I think entirely in pictures. I don't think in words and all my memory, everything I've got in my mind is all pictures.... Half the engineers can't spell.... It's just simply a thought process. It's the way we think. It's entirely different.... People that do design are horrible writers.... In high school, I did drafting all the way through and just loved it. I just knew it, understood it well and the concept of geometric shapes. I've always had a really clear.... Later, when talking about design, he said, "[Design is] highly creative.... It's highly stimulating. It requires new thought.... You can't even break it down into steps that much. There's two major steps. There's functionality. There's embodiment. Two steps." Rob makes a strong connection between pictures and design. The ability to "think in pictures" seems to be at odds with the ability to think in words. By extension, those that are able to think well "in words" cannot be expected to be good (engineering) designers. In terms of the language metaphor, it appears a person can master either one form of language or the other, but not both. It is also interesting to note that Rob speaks of being "clear" with regards to his love and ability to do drafting. The creative aspect is very important to him in design and it may be the reason that he waffles with regards to whether or not design can be broken down into steps: the methodological approach implied by steps counters some of the freedom and mystery that surround creativity.

Jane's concept of design went like this: "When I think of design, I think of having a problem and finding a solution to it and designing around it. But, then, you can design lots of things. You don't have to have a problem and a solution. I can just design something for fun, or for artistic merit, or whatever. But, when I think of it, I think of problem, solution and you design to that." Jane's idea of "designing around it" indicates her concept of engineering design involves making compromises to go from the "problem" to the "solution". Design, in her mind, is not a straightforward process. She then proceeds to offer a new, less formal definition of design. Of her own accord, however, she seems to renege on this view of design and restates her original answer. Her decision to renege on her "deviant" behaviour is interesting when coupled with her efforts to take certain electives: "We're restricted in the complementary studies that we can take, I mean, non-scientific options.... There were some artistics courses you could take, but not all of it. So, when I wanted to take black and white photography, they wouldn't let me." When asked what the reason was, she said, "They said it was too non-scientific." Once again, her "deviance" was reined in, this time from an outside source. In trying to take the elective, she had been taught not to wander too far from the "scientific" way of thinking. She had perhaps carried this and similar experiences to her concept of design and decided that her more personal concept of design was inappropriate and should be abandoned. It is also interesting to note that it was not that the course was "non-scientific", but that it was "*too* non-scientific". There are, in the engineering world, different gradations of "non-scientificism" to which we must be wary.

6. Summary

Discourse analysis can be used to gain an understanding of the engineering culture. This understanding is crucial to the development of courses aimed at creating a particular culture or a shift in culture within the engineering student body. Culture and its accompanying values can be revealed through the study of both written materials and spoken word.

The written materials studied indicated a desire to keep engineering design within the confines of rational, logical approaches and clarity must be maintained at every step. The design activity begins with a rational need and follows the scientific paradigm as much as possible. The rationality upon which engineers have built the profession go back to antiquity. Engineering design is a natural offspring of civilization as demonstrated by the progression of language, drawing (another form of language), drafting and design. Engineering continues to be an integral part of society as evidenced by its concern for economic issues, greatly valued by society.

Students responses varied. Some students made a strong connection between "picture" and design. Some spoke of creativity. There appeared to be some unresolved issues concerning the tendency toward convergent thinking using the formal design methods and the more divergent aspects of creativity.

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