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USING QUALITATIVE RESEARCH METHODS IN ENGINEERING DESIGN RESEARCH

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ABSTRACT
In order to support successful strategies in design education and practice, we must have a deep understanding of the complex dynamics of design processes, teams, contexts, and systems. Facilitating this understanding of engineering design requires research methodologies that can capture the nature of the design process from a diversity of aspects such cognitive, creative, social, organizational, and experiential. Traditionally, research in engineering design has focused on quantitative methodologies whose constructs are familiar to engineers. Our assertion here that qualitative research methodologies that are less familiar to engineers can provide unique scientific insights into the study of engineering design, enabling new findings not obtainable via quantitative methodologies. In this paper we provide an overview of qualitative research methods, outline key opportunities where qualitative methods can be used to enhance engineering design research, and present a case example of a qualitative study on interdisciplinary interactions in complex system design.

Keywords: qualitative research, interdisciplinary interactions, research methods

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1 INTRODUCTION

Design is central to engineering. Just as accreditation policies for engineering programs emphasize an ability to design as an outcome and measure of professional preparation (ABET Board of Directors, 2007), statements on the future of engineering emphasize the need for engineering graduates to design for the betterment of the world (e.g., Committee on the Engineer of 2020, 2004; Duderstadt, 2008; Sheppard, Macatanga, Colby & Sullivan, 2009). In order to support successful strategies in design education and practice, we must have a deep understanding of the complex dynamics of design processes, teams, contexts, and systems. Facilitating this understanding of engineering design requires research methodologies that can capture the nature of the design process from a diversity of aspects, i.e., cognitive, creative, social, organizational, and experiential. While a large majority of research in engineering design has focused on quantitative methodologies, there are numerous researchers using qualitative methods to explore design research questions (e.g., Adams, Daly, Mann & Dall'Alba, 2011; Ahmed, Wallace, Blesing, 2003; Ball & Ormerod, 2000; Bucciarelli, 1988; Cross & Cross, 1988; Daly, Adams, & Bodner, 2012; Sutton & Hargadon, 1996; Yilmaz, Christian, Daly, Seifert, & Gonzalez, 2011; Zoltowski, Oakes, & Cardella, 2011). The goal of our work is not to introduce the idea of qualitative methods to the field of design research. Instead, we describe and emphasize the value of a qualitative approach for researchers unfamiliar with these techniques in order to support broader adoption of these methods when they are appropriate for the research goals.

In this paper we outline key opportunities where qualitative methods can be used to enhance engineering design research and highlight existing design research guided by qualitative methods. We begin with an overview of qualitative research methods, and also discuss specific strategies for structuring qualitative research efforts to study engineering design. While exemplars from existing literature are used throughout the paper, a recently conducted case study on the design of large complex systems is used to illustrate qualitative data collection and analysis, the type of results that may be anticipated, and the challenges and opportunities afforded by a qualitative approach. Using the case study focused on interdisciplinary interactions in designing large-scale complex engineered systems, we will show that a qualitative approach for studying such a technically complex design product produces findings not attainable with a quantitative approach.

2 PRINCIPLES OF QUALITATIVE RESEARCH METHODS

To trained engineering researchers, qualitative methods may seem to contradict intuition in the design of an investigation; in a study of engineers learning this methodology, Borrego (2007) found that engineers who were used to the traditional engineering research methods struggled to understand a qualitative research approach. Thus, understanding the foundations of qualitative research is a useful starting point to lead into a discussion of our qualitative case study. We summarize key principles of qualitative methods below and sometimes compare a qualitative approach to a quantitative one, not to lead the reader to think that one is better or worse, but instead to help make visible the distinctions, value, and outcomes of each type of approach.

The goals of qualitative research are illumination, understanding, and extrapolation of findings to similar situations (Hoepfl, 1997). This is distinct from the goals of quantitative studies, which include causal determination, prediction, and generalization of findings. While findings in qualitative research can sometimes be summarized quantitatively, the nature of research questions appropriate for qualitative analysis often require findings to be reported as be rich, "thick" descriptions (Patton, 2001). Qualitative investigations do not attempt to control for the context, but instead seek to describe it in-depth, so as to incorporate the context into deriving and explaining research findings (Patton, 2001). Its emphasis is on the context within which the study occurs, allowing for research questions of the nature: What is occurring? How is something occurring? Why is something occurring? What impacts the occurrence of a phenomenon? (Borrego, Douglas, Amelink, 2009; Van Note Chism, Douglas, & Hilson, 2008).

Driven by the goal of detail, methods like interviews and observations are dominant in qualitative work (Golafshani, 2003; Patton, 2001; Van Note Chism, Douglas, & Hilson, 2008), but also include analysis of other textual forms of data, such as open-ended surveys, dialogues, focus groups, and documents (Borrego, Douglas, Amelink, 2009; Leydens, Moskal, & Pavelich, 2004; Patton, 2001). While instrumentation in traditional engineering experiments is objectively created, qualitative analysis instrumentation, such as interview and observation protocols, must be grounded in literature and piloted to assure validity and reliability of the instrument. Additionally, the researcher involved in executing the protocol, i.e., the interviewer or observer, is part of the instrumentation, which must be taken into account in demonstrating validity and reliability. Often, this is a clear, repeatable procedure with unbiased questions and grounded in literature.

One of the strengths of qualitative research is that it allows new phenomena to be identified (Borrego, Douglas, Amelink, 2009; Patton, 2001). These phenomena are ones that cannot be identified a priori and emerge from in-depth data collection. Borrego et al. (2009) cite an example of emergent phenomena in engineering research:

> McLoughlin (2005) identified a new type of gender bias in her study of women in engineering. Because this type of bias had not been previously identified, a quantitative study of gender bias would not have revealed it. Only by examining the words of the participants and interpreting those words with qualitative analysis techniques was McLoughlin able to identify a new phenomenon. Her results now provide opportunities for additional qualitative and quantitative studies to examine this phenomenon further.

Data analysis in qualitative research can be inductive, deductive, or a combination of both (Crabtree & Miller, 1999; Fereday & Muir-Cochrane, 2006; Leydens, Moskal, & Pavelich, 2004; Patton, 2001). Deductive analysis refers to determining a coding scheme prior to looking at the data, while inductive analysis refers to developing themes emergently based on patterns in the data. As determining a coding scheme a priori is often impossible in qualitative studies, inductive analysis is a more common approach (Borrego, Douglas, Amelink, 2009; Frankel & Devers, 2000; Koro-Ljungberg).

In quantitative studies, sample size goals are large numbers, however, in qualitative studies participant numbers are generally small, so that the population can be explored in depth (Borrego et al., 2009; Patton, 2001). Just like any research approach, the appropriate sample size for a qualitative approach is based on what is necessary to answer the research questions. Thus, if the question relies on very detailed information, a small sample could be appropriate, even as small as a case study of one (Marshall, 1996). While a random sample provides the best opportunity to generalize to an entire population, as is a key value and outcome of quantitative work, a random sample is not the most effective way to learn about complex issues related to human behavior, where the goal is to describe a phenomenon in enough depth that the full meaning of what occurs is understood. Thus, generalizability is not the goal of most qualitative work. This does not decrease its value; instead it yields different types of outcomes, such as rich descriptions of how phenomena occur in context.

Qualitative research done properly is as rigorous as positivist approaches of quantitative studies. However, the methods of data collection and analysis are different, thus, assessing rigor and validity differs from assessing rigor and validity in traditional engineering research (Hoaglin et al., 1982; Koro-Ljungberg & Douglas, 2008; Van Note Chism, Douglas, & Hilson, 2008). While rigor is represented with the terms reliability and validity in quantitative research, qualitative research uses terms such as trustworthiness and transferability (Borrego, et al., 2009; Golafshani, 2003; Leydens, Moskal, & Pavelich, 2004; Patton, 2001). Trustworthiness means that the researcher collects and analyzes the data in a systematic way and presents the data and the synthesis and interpretation of data in a transparent way for others. A reader of the research should be able to see how the collected data informed the findings. This means that research papers written on qualitative studies are often longer than quantitative study reports. In addition to rich description and transparency, triangulation, meaning the use of multiple kinds of data or multiple methods to collect data, is another approach used to increase trustworthiness in qualitative research (Patton, 2001). Transferability refers to the extent to which research findings can apply to contexts other than the study context from which the findings emerged (Leydens et al., 2004). Borrego et al. (2009) describe transferability as having enough thick description of a specific context that will allow readers of the research to make connections to their own situation.

As with any research methodology, there are limitations. For example, the quality of the study is heavily depended on the individual skills of the researcher and subject to biases of the researcher. Additionally, the volume of data to collect and analyze is very time consuming. As previously discussed, qualitative findings are not often generalizable. Qualitative findings can serve as a foundation for quantitative studies or qualitative studies can help explore the how and why questions emerging from a quantitative study. Mixed-methods approaches, combining qualitative and quantitative methods, are sometimes used to investigate a research goal with multiple perspectives, taking advantage of the strengths of qualitative and quantitative methods.

Within qualitative methods, there are various types of approaches (Case & Light, 2011; Patton, 2001). In the case study we present in this paper, we use an ethnographic approach, described as "a written account of the cultural life of a social group, organization or community which may focus on a particular aspect of life in that setting" (Watson, 2008, as referenced by Humphreys and Watson, 2009). The ethnographic research approach entails a researcher becoming immersed within the social context being studied (Gioia and Chittipeddi, 1991). Hence, "every interaction and experience constitutes data to be interpreted as a member of the organization – and as a researcher" (Gioia and Chittipeddi, 1991). There are many other qualitative approaches, but our focus here is on qualitative methods in general, and ethnography, as it applies to our research.

3 QUALITATIVE METHODS IN ENGINEERING DESIGN RESEARCH

Numerous studies in engineering design have used qualitative approaches. For example, Bucciarelli (1988) used an ethnographic approach to illustrate social processes at play in practitioner design teams. Ahmed, Wallace, & Blessing (2003) observed and interviewed novice and expert designers to look for patterns in how each approached design tasks. Other studies using qualitative methods in engineering design have characterized cross-disciplinary design behaviors (Adams, Mann, Jordan, Daly, 2009), investigated ways practitioners approach design work (Daly, Adams, & Bodner, 2012), compared strategies of expert designers (Cross & Cross, 1988), developed a framework for human-centered design experiences (Zoltowski, Oakes, & Cardella, 2012), and extracted strategies for generating design solutions during concept generation (Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012).

Using these existing examples of qualitative research in engineering design as well as foundational resources on qualitative methods (e.g., Creswell, 2002; Patton, 2001) to guide our work, we developed a study to investigate interdisciplinary interactions during the research, development, and early conceptual design phases of large-scale complex engineered systems. The following section describes the research, including background related to the research goals, the methods we employed, and examples of key findings that the qualitative approach allowed to emerge.

4 A CASE EXAMPLE: INTERDISCIPLINARY INTERACTIONS IN LARGE COMPLEX DESIGN SYSTEMS

4.1 Introduction of the Research Problem

This study investigated interdisciplinary interactions that take place during the research, development, and early conceptual design phases of Large-scale Complex Engineered Systems (LaCES) such as aerospace vehicles. These interactions occur throughout a large engineering development organization and become the initial conditions of the design and systems engineering process, ultimately leading to the complete design and development of a viable system. This case study focused on (1) providing deep descriptions of the related engineering and organizational practices of interdisciplinary interactions during research, development, and early conceptual design, and (2) deriving an explanatory integrative framework that provides a more theoretical perspective on these practices.

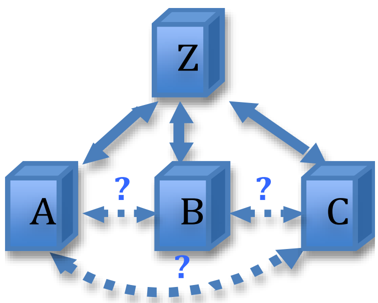

Figure 1. Cross-disciplinary Interactions

The challenges of cross-disciplinary processes in engineering design are complex and evolving. They involve both technical and social processes. The case study delved into the interdependence of the disciplines and the associated non-hierarchical interactive practices *between* researchers in the early design process. The interactions (indicated by the dotted lines in Figure 1) have implications for the engineered system and the engineering organization that designs it. Developing a deeper understanding of these interdisciplinary interactions were the focus of the case study.

4.2 Research Approach

The research questions guiding our work included: 1) *What are current perspectives on and practices in interdisciplinary interactions during research and development and early design of LaCES?* 2) *Why might these perspectives and practices prevail?* These research questions were well suited to a qualitative approach, particularly an ethnographic study, because our goal was to describe and conceptualize a wide variety of perspectives (Boeije, 2002; Brannick and Coghlan, 2007; Humphreys and Watson, 2009). Our goal was a holistic perspective of LaCES that would capture the social, historical, and temporal contexts impacting the research and development of LaCES (Leydens, Moskal, and Pavelich, 2004). Additionally, qualitative methods also facilitated our goal for a formative study "intended to help improve existing practice rather than simply to determine the outcomes of the program or practice being studied" (Scriven, 1967, 1991 as referenced in Maxwell, 1998).

In this research, there were many open questions and little previous work on which to build a hypothesis about the barriers and enablers of interdisciplinary interactions in LaCES. Additionally, we could not influence the environment in such a way as to run a controlled experiment and attempts to do so would exclude some of the data that were important to collect in the study. For example, we sought to understand the totality of the organizational context including culture, norms, hidden agendas, etc. Thus, we encouraged our participants to expand upon their experiences to the fullest.

One option to study the research and development practices of LaCES could have been to use a quantitative approach, recruiting a large random sample of those whose work is related to LaCES and collecting data through a self-report survey where participants could be asked to rate a number of items as having an influence on their interdisciplinary interactions. However, we realized limitation with this approach; for example, we would need to develop a survey instrument that listed all of the important factors that play a role in interdisciplinary interactions. Due to the limited research in the area, this list of factors would be anecdotal and biased by our own experiences. The list provided to participants might not have captured the real barriers or enablers of interdisciplinary work. Additionally, interdisciplinary interactions are complex phenomena and participants are likely to interpret what they are in different ways. A multiple choice survey format may not have provided us with sufficient detail to understand the important distinctions across participants or to discern intricacies in how one person's definition compared to another's. Such a survey would result in a limited analysis of the complex phenomena under study, greatly limiting the ability to explain why or how these interactions occurred or compare the ways a factor had an impact across multiple participants. Using qualitative methods for this study allowed the participants to freely describe the real barriers or enablers of interdisciplinary interactions by giving in-depth examples they have experienced in practice. Their answers were not confined by multiple-choice options that would be limited by the available research findings. Variations in experience among the participants were also captured via the open-ended nature of our qualitative approach.

As we emphasized earlier, the research questions should determine the research method (Creswell, 2002), not the contrary. For this study we sought to investigate why and how interdisciplinary interactions occurred, the importance various players placed on these interactions, how these interactions were defined by people in different organizational roles, and what factors supported and impeded the occurrence of these interactions. To answer these questions, we needed to collect in-depth data to understand the context and experiences of practicing engineers and scientists. A qualitative approach allowed us to be naturalistic, investigating the real-world setting of LaCES without manipulating it, and facilitating our goal to understand this phenomenon in a specific context (Denzin & Lincoln, 2000; Patton, 2001). While quantitative methods would also add different insights to this study, the primary research goals were best suited by qualitative methods.

4.3 Methods Employed in Our Qualitative Investigation

The structure of the research design included a triangulation approach where data collected from surveys, semi-structured interviews, and ethnographic interactions and observations were integrated. Each data collection method provided insight into distinct facets of interdisciplinary interactions during engineering systems R&D. The survey focused on identifying current perspectives on interdisciplinary interactions by sampling a diverse group of 62 leaders that spanned industry, government, and academia. They provided a unique assessment of current thinking and took place prior to the interviews, which also guided our interview design and analysis. The semi-structured interviews focused on allowing us to obtain detailed, concrete examples of cross-disciplinary practices through the purposeful participant recruitment of 20 practitioners with diverse experiences and responsibilities in aerospace R&D and conceptual design. The interviews offered comparative data "for understanding the world from the view of those studied" and helped to "unfold the meaning of their experiences" (Pratt, 2009; Kvale and Brinkmann, 2008). Interactional and observational data collected through an insider ethnography approach provided a rich, descriptive account of the cultural and organizational work life of R&D engineers in aerospace (Humphreys and Watson, 2009).

Our choices in the research design of this study were guided by principles of rigor in qualitative studies. We collected data using three different methods to allow for synthesis and strengthen findings during analysis. This approach aided in reducing researcher bias and improving the trustworthiness of the findings. Each data collection method unearthed different aspects of interdisciplinary interactions thereby significantly improving the "confirmability" of the findings. Additionally, each of the three data collection methods enabled the opportunity for "negative cases" that challenged preliminary themes. Peer examination from researchers in engineering, organization science, engineering education, and psychology further aided in cross checking interpretations.

4.4 Data Collection and Analysis

In this paper we focus on highlighting valuable insights revealed in our interview analysis. However, we summarize the survey and ethnographic interactions here to demonstration how these data shaped the interview design and analysis. The survey focused on obtaining short, written answers to seven open-ended questions such as: "*Please describe things that encourage interdisciplinary interactions"* and *"Please describe the obstacles to interdisciplinary interaction."* Ethnographic research for this study was primarily conducted in aerospace R&D settings via 20 years of insider involvement and extensive interaction with a wide variety of aerospace R&D and design entities. The long duration of the insider ethnography provided critical insight to discern "the more subtle, implicit underlying assumptions that are not often readily accessible through observation or interview methods alone" (Emerson, Fretz, and Shaw, 2011). Further details regarding the survey and the ethnographic portions of this study are provided in McGowan, Daly, Baker, Papalambros, & Seifert (2013).

Semi-structured interviews were conducted with 20 participants and were focused on obtaining rich descriptions of engineering practice. The 20 participants were carefully chosen to provide a balanced sample considering years of experience, job site locations, leadership and staff positions, and diversity of engineering tasks. Example questions asked during these interviews included: "*I'm interested in hearing about an experience you had in working with someone outside of (their home area of work). Tell me about it." "Can you describe what challenges you faced?" "I'd like to hear about what you gained from the experience?"*

Data analysis was inductive, guided by constant comparison methods, in which themes were identified, continuously compared to newly emergent themes, and revised based on the comparison (Boeiji, 2002). As is common in a qualitative study, data from all research methods (survey, interview, and ethnographic data) were integrated and re-coded as new findings emerged and the research design was adjusted accordingly.

4.5 Benefits of the Qualitative Approach: A Look at Two Key Findings

With goals of providing an in-depth analysis and portrait of practice of interdisciplinary interactions in R&D, qualitative methods provided a means to synthesize the complexity that underlies engineering practice in the domain of large-scale complex systems. Several findings emerged from this study that would be very difficult, if not impossible, to obtain via quantitative methods. In this section we will highlight a few examples from findings of the study to illuminate this topic. While the findings from the study were generally informed from the integration of the survey, interview, and ethnographic data, we separate them here for clarity.

The survey instrument used open-ended questions rather than multiple-choice responses. Though the latter allows for more quantitative results, the former provided an opportunity for participants to speak freely with minimal prompting, allowing for a greater diversity of responses. In this scenario, consistency of responses increases the validity of the findings. For example, there were several surprises in the survey data; one of which resulted from the consistency of an unexpected response and another from a lack of expected responses 1) responses related to social science aspects exceeded the responses related to engineering or mechanical aspects by an extremely wide margin; and, 2) the near absence of responses related to commonly used integration functions such as multidisciplinary design optimization (MDO), systems analysis, systems engineering, and the role of a chief engineer. The first surprise from the data is rather significant: perceptions regarding interdisciplinary interactions in engineering R&D are more related to social science aspects than engineering aspects. An indicator is the large number of occurrences of responses related to interrelationships between people, but also the detail in which people explained these relationship factors: conflicts, coordination, relationships, proximity to colleagues, understanding others, teaming, group dynamics, interactive activities, emotions, incentives, and the most commonly referenced topics of communication and language. Interestingly, the referenced interrelation topics were not about interfaces with mathematical models, software, or hardware. As these topics are more familiar to engineers, a more quantitatively designed survey with prescribed, multiple-choice answers would likely have focused responses toward to mathematical models, software, and hardware interface challenges. Although answers regarding these types of engineering interface challenges would yield important data, it would also have left us uninformed of the topics most important to practicing engineers. As the motivation for this study is to better understand interdisciplinary interactions so as to improve practice and the resulting system designs, uncovering the realities of practice is central to achieving the study goals.

During the interviews, participants also discussed social challenges, but in greater depth and with examples from their own experiences. A respondent with significant experience in Multidisciplinary Design, Analysis, and Optimization (MDAO) noted the following:

> *"We were working with ... six different groups trying to get software requirements for what we stated as a multi-disciplinary software framework. The biggest challenge was vocabulary without a doubt. I think I spent three hours one time talking—arguing—with somebody over something that six months later in retrospect I realized that we were arguing over the exact same thing*."

This respondent and many others noted communication and organizational challenges repeatedly. At the end of this interview, the interviewer asked, *"Is there something else you would like to say?"* This respondent's response identifies a research direction not frequently noted in the literature.

> *"I think the most important part of MDAO is really the interpersonal part. I think we've—as a discipline—because I consider myself an MDAO researcher—I think we've got a handle on, or we're moving toward getting a handle on the technical aspects of it. There's always more research to be done but we understand very well about systems and optimization and configuration and things like that. Computational costs are still a challenge but we're working on it. We haven't really started to address the interpersonal issues. I think that's the most important."*

The focus on human interfaces rather than engineering interfaces may relate to the second surprising finding from the study about traditional engineering design integration functions such as MDO, systems analysis, systems engineering, and the role of a chief engineer. This finding was identified from the nearly complete absence of survey responses related to these commonly used integration functions. This might suggest that these traditional integration functions may not address the social and organizational aspects noted in the survey responses. During the interviews, respondents also noted that most of the interdisciplinary interactions that they do were accomplished without the assistance of these organizational roles. Further, they did not see these roles are critical to their interdisciplinary efforts. This finding was quite surprising. A more quantitative study may have focused the research efforts on these organizational roles and missed other realities of actual engineering practice. However by allowing the participants to tell us their anonymous thoughts without "controlling the responses" via prescribed multiple-choice answers in the survey or the interview, much was learned that would not have been guessed a priori.

During the study we also learned firsthand insights regarding common engineering interface methods such as the use of requirements. Below, we have sequentially excerpted several quotations from the same interview with a senior research engineer (over 25 years experience) who is considered a subject matter expert in a single discipline, but also serves as a respected multidisciplinary team leader. This respondent described his/her journey from working primarily in a single discipline toward gaining more understanding of the system design needs and working with many other disciplines. The respondent's experience regarding the use of requirements in system design provides an illuminating perspective.

> *"Understanding the application is realizing that my [discipline] can influence a lot more than the set of requirements that you gave me. So, the set of requirements was what you thought I needed to know. ... [In single discipline research] you're trying to focus on the requirements people have told you about. You're missing out on the requirements that nobody told you about. .... So, the risk in just the [single discipline work] is that you're limited by the requirements that somebody has given you and the information that somebody has given you. ... They're telling you that I need this [A] with this [B] and this [C] capability. ... I think that it forced you into a single functionality. So, without understanding some of the other systems' needs, big system needs, you can't take advantage of multi-functionality very easily, and you can't design for multi-functionality because you don't know that "oh, this is also a requirement but it wasn't anything anybody told you was a requirement because maybe they didn't know it was a requirement." ... So, I can take those numbers and I can build you something that will meet those requirements, but it's only gonna meet those requirements because those are the only things I know it needs to do. Now, well, it gives you a solution but is it the best solution? ... What we're seeing with the [discipline 1] and [discipline 2] people talking to each other now, all of a sudden the [discipline 2] people go, "You've got a [thing] that can do that? Oh, well let me change my requirement. I didn't know you could do that. I gave you something I thought you could do." ... I think that what I see happening is that it causes everybody to go back and question the requirements and really understand, is this actually the requirement or is this just the way we've always done things?"*

This respondent's comments emerged from reflecting on his/her own experience, bringing to light important subtleties of design process that may be ignored. Appreciating that the use of well-defined requirements is a necessary element of good design practice, this experienced researcher noted some unintended consequences of using requirements when blending a group of discipline experts. One key finding from these data is that regardless of the quality of the requirements provided in developing a system design, requirements alone may "blind" the design team of untapped capabilities within each discipline that may offer innovative improvements to the overall system.

As noted earlier, ethnography was also a necessary element of this study as it provided a means of analyzing and interpreting the survey and interview data. As noted by Morgan: "an organization's culture always runs much deeper than its published aims and its members' behavior." Edward's also notes that insider ethnographers have "a sensitivity to and awareness of histories and the slow tidal changes which may work their way through organizations over a decade or more. Not all change is rapid, visible and explicable." In this study, ethnography was critical "to participate in the minds" of the respondents and comprehend their setting (Lofland and Lofland, 1995). This aided in fostering an interpretation of aspects such as insider agendas, "silent" divisions between work groups, and internal jargon (Edwards, 2002, Brannick and Coghlan, 2007).

5 CONCLUSIONS

The brief examples presented above give a glimpse of the depth of findings that can come from a qualitative approach. For studying design, qualitative methods may provide a useful augmentation to quantitative studies to more richly illuminate processes, cultures, relationships, and motivations that impact design. As design is a social, artistic, organizational, cultural, political, and mechanical activity, only a diversity of research methods can help us tap its originations and resources to enable improvements beyond our current ideas.

The ability to investigate design approaches, processes, and contexts in deep ways using rigorous qualitative approaches holds the promise of facilitating new discoveries, eventually leading to improvements in the field, including directing more efficient design processes, creating supporting design contexts for collaboration, and supporting innovation through design. This paper described the foundations of qualitative methods and a case example in hopes of supporting continuing conversations and practice of qualitative research in engineering design research.

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