

# Cognitive Ethnographies of Heterogeneous Engineering Design

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**Abstract:** This is an empirical ethnographic study of how engineers in both undergraduate design courses and the professional workplace engage in engineering design. The findings suggest that the organizational contexts constitute processes of design differently, in ways that challenge the typical rhetoric of undergraduate education that project courses are intended to provide students with “real world” experience.

## Introduction

Design is “widely considered to be the central or distinguishing activity of engineering” (Dym, Agogino, Eris, Frey, & Leifer, 2005), and yet it remains an insufficiently researched and understood topic (Barley, 2004; Dym et al., 2005; Stevens, Johri, & O'Connor, 2013). From the perspective of engineering education, where a “disconnect” between professional engineering practices and school-based practices is an oft-discussed limitation, this sparseness of research on professional engineering design is both puzzling and troubling (Stevens et al., 2013). As Stevens et al. (2013) argue, trustworthy and specific representations of real engineering practices are necessary to inform attempts to prepare future engineers. The present study attempts to inform these efforts through comparative ethnographic research on design practices in the undergraduate curriculum and in the workplace.

## Theoretical Framework

The theoretical framework for examining practices of engineering design is provided by the notion of “heterogeneous engineering” (Law, 1987), which has been developed in Social Studies of Science and Technology as a way of countering a received “ideology of engineering” (Williams, 2002) that reduces engineering to the application of technical principles and processes in the service of solving technical problems. The notion of heterogeneous engineering, in contrast, sees engineers as “system builders” (Law, 1987, p. 112) who are involved in the active stabilization of systems that are composed of heterogeneous elements, both human and nonhuman. In this sense, what is being engineered is not just a technical object; rather, engineering *is* productive of objects, but also of persons, institutions, and everything that is part of the system that constitutes the object.

Suchman (2000) developed the notion of heterogeneous engineering in organizations, noting the implications of the perspective for learning and becoming. In the context of this project, the heterogeneous elements being coordinated can include the technical principles and processes held in high esteem within the technicist ideology of engineering. However, these principles and processes do not determine the course of engineering work; rather, they are flexibly adapted as resources in the flow of practice. They are, Suchman claims, appropriated in forms of “artful compliance” and “endless small forms of practical ‘subversion, taken up in the name of getting the work of the organization done” (p. 313). Suchman’s focus on the organizational context of the appropriation of the tools of technicist rationality points to the importance of understanding the organization, institutional framing of engineering activity. For the learning sciences, this focus calls for understanding notions of “authenticity” in ways that go beyond the modeling of epistemic practices of disciplines (Brown, Collins, & Duguid, 1989) and using these as the basis for enculturation into a profession or discipline.

## Methodology

The present study attends to the location of engineering design in different organizational settings, as a way of examining the nature of purported “disconnects” between professional engineering design practices and those taking place in the undergraduate curriculum. Our core methodology is that of “cognitive ethnography” (Hutchins, 1995), which examines how cognitive tasks, in our case design, are accomplished within “functional systems” (Hutchins, 1995) constituted of heterogeneous elements, both human and nonhuman. Our focus is on “how the work of the organization” (Suchman, 2000) gets done through the process of design. The research has three unique settings: a general engineering freshman design course, a senior mechanical engineering design course, and small to medium sized professional engineering companies in the same geographic region. Specifically from this project, we want to answer the following research questions: In what ways are there disconnects between the way engineering design is constructed in undergraduate courses compared to professional engineering design environments? What will make university design practices authentic to becoming a professional engineer?

This qualitative research study was approached with techniques for doing fieldwork in modern societies (Czarniawska, 2007). A variety of fieldwork methods, both direct and indirect, were used to capture all the elements of participants' activities in the design process. The observations include all parties that impact the design process, such as those organizing freshmen and senior design, employees in the machine shop, and clients. The researchers engaged in participant observations, while taking field notes and audio/video recording the meetings. The researchers followed the design teams through each step of the process. Additionally, all materials and artifacts that were produced by participants during their work were collected, such as copies of paper/electronic documents and photographs of temporary surfaces like whiteboards where participants used while working. There have been over 400 hours of observation and over 200 documents collected from following the design teams.

## Preliminary Findings

In this section, we report preliminary findings of the study; these findings will be developed as the study continues. Our initial findings are suggestive that the organizational contexts constitute processes of design differently, in ways that challenge the typical rhetoric of undergraduate education that project courses are intended to provide students with "real world" experience. Key among these findings are that, at the undergraduate level, abstracted technical descriptions of professional expertise serve a central role, in the form of, for example, design methodologies that are intended to serve as the basis for student work. Instructors of these courses—sometimes without substantive expertise in the design of "products"—rely on these epistemic forms to frame a learning trajectory through the course for students, and students' performance is thus graded on the basis of their proficiency with these technicist forms. Moreover, the organizational trajectory for these design courses appears to end with the semester; unlike sequenced courses in, for example, physics and calculus, design courses are not formally connected within the curriculum to any other courses. Finally, the "products" being produced—the contingently stabilized objects, in the heterogeneous engineering perspective—themselves may often have no trajectory: sometimes they are disposed of or disassembled for reuse of parts in future project classes, and are not always core aspect of the constitution of the organization. In contrast, at the professional level, trajectories are often organized around technical objects, and organizational and individual accomplishment is assessed on the basis of the success of these stabilized objects. Representations of expert performance, such as design methodologies, are not central aspects of the evaluation of performance, but rather are "subversively" used (Suchman, 2000) in order to get the work of the organization done.

## Significance

We expect the findings from this project to both contribute to our understanding of the nature of the structure and practice of engineering design and to have direct relevance to ongoing attempts to redesign the engineering education curricula, as well as add to conversations in the learning sciences on the nature of authentic practice.

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