Work-in-Progress: Novel Ethnographic Approaches for Investigating Engineering Practice

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Introduction

There remains a limited amount of research on professional engineering work practices [1]. This deficiency is troubling because engineering education is organized and reorganized based on claims and assumptions about what professional engineering work is or will be. Without well-researched and trustworthy representations of practice, it is questionable whether engineering educators can adequately prepare future engineers for workplace realities. Although it is important that the preparation of future engineers not be tied solely to the workforce, there is a significant "disconnect between engineers in practice and engineers in academe" [2, p. 18]. If educators want to prepare students for professional success – including by assuming roles as future leaders and change agents – concrete images of engineering work are critical resources for rethinking engineering education [1]. The need for such resources is even more urgent given ongoing changes to engineering work under the forces of globalization, new organizational configurations, and new technologies of communication, design, and production. More research is needed to document images that are often discounted by students and even faculty, i.e., portrayals of engineering practice that emphasize its non-technical and non-calculative sides, including work processes and dynamics that involve social and cultural dimensions [3-4].

The aim of this work-in-progress paper is to introduce an exploratory project that will test innovative approaches to data collection and analysis for rapidly generating new knowledge about engineering practice. Traditionally, engineering practices have been studied using individual interviews or in-depth ethnographic field research, the latter requiring researchers to embed themselves as participant observers in the workplace. Yet technical work increasingly involves open workspaces and geographically distributed teams, frequent changes in job roles and team composition, and many layers of digital abstraction and collaboration. It thus may not be feasible or optimal to perform on-site research for extended periods of time. The main aim of this paper is to introduce method innovations for conducting field research that can potentially generate higher quality data more efficiently. Before doing so, we briefly review prior research on engineering practice.

Prior Work

To date, most research on engineering practice has utilized field study methods [1], which have the advantage of being able to shed light on practices in context. Most field studies have a broadly ethnographic goal, namely to adequately and thickly describe the specific qualities of practices, to understand and represent the meaning of those practices for people who participate in them, and to understand unique and locally situated forms of work culture and social organization. In the context of engineering practices, field studies have largely been conducted in the workplace using observations and interviews. These include studies across both disciplines and time, beginning with pioneering works such as Barnes' comparative, observational study of technical groups in industry [5], and Youngman et al.'s in-depth, multi-modal analysis of engineering job roles and work activities [6]. The 1980s and 1990s saw a new wave of engineering practice research (e.g., [7-13]), much of it borrowing from the ethnographic and

observational traditions of Science and Technology Studies (STS) and other social science fields. Research on engineering practice has gradually accumulated and diversified in recent decades, as summarized in previous publications (e.g., [1, 14, 15]).

While this is an inspiring body of work, three points are worth emphasizing. First, it represents a small and relatively marginal slice of scholarship in engineering education, where studies of teaching and learning in formal educational settings remain predominant [16]. Second, these and other studies continue to rely on conventional data collection methods, including traditional observational studies and interviews. In fact, the relative prevalence of interviews is a concern given that interview data is usually easier to collect but also at higher risk for generating incomplete or inaccurate characterizations of practice due to the potential for various biases [17]. Third and finally, research on professional practice is perennially threatened with obsolescence due to ongoing shifts in the job roles, task demands, study settings, and demographics of engineering. We now turn to four specific, contemporary trends that underscore the need for more research and methodological innovations.

Trends/Challenges

The **digitization of technical work practices** is one of the most fast-paced and significant kinds of change in engineering. In addition to using new communication technologies, such as Slack, engineers are making increased use of computational technologies to model and convert the physical in digital forms [18-19], and manage complex workflows. This change is significant and has been unfolding for decades, as described by Zussman: "engineering practice today is characterized by a near total absence of that physical, hands-on labor that is a central attribute of craft work. Engineers manipulate symbols that refer to physical objects, mostly equipment and products, but they do not manipulate those objects themselves" [20, p. 77]. Thus, the *lingua franca* of engineering work is increasingly realized in "digital form." The use of digital communication tools and workflow platforms also means that engineers can, theoretically, work from anywhere, anytime. This may entail considerable efficiency and flexibility advantages for companies and employees, but can also introduce new difficulties as communication channels and reporting relationships are reshaped, and as work-life balance becomes more difficult to manage. The confluence of these trends calls for research innovations to enable the study of the myriad digital artifacts and "traces" created by employees.

A second and related shift unfolding in tandem with the use of information technology is the increasingly **globalized nature of engineering work practices**. Networked technologies allow engineering work to bypass the traditional boundaries of a workday, moving projects along "24/7" and "offshoring" significant parts of technical projects. Ideology may outrun reality with respect to these globally distributed configurations and there remain opportunities to better understand emerging, networked form of practices, including how cultural differences are negotiated [21]. A related trend is the use of micro-tasks to distribute labor and thereby creating new forms of practice that rely on the input of thousands of participants from across the globe, in turn creating new kinds of power and justice issues [22]. Such trends create barriers to, as well as opportunities for, conducting research on practice.

Third, the networks in which employees are embedded have shifted, becoming more **cross-organizational and distributed in nature**. This can facilitate learning and knowledge sharing, but can also create barriers for studying the many informal and formal networks that transcend conventional structures. Many of these networks also span geographic and/or cultural boundaries. Spanning these boundaries not only necessitates using various technologies for communication but can also involve differences in language and other communicative practices, technical training, ethical grounding, and regulatory environments. The use of social media platforms like LinkedIn is also reshaping what it means to be a professional and engage in technical work. Rather than mainly being embedded in physical, context-bound communities of practice (CoP), engineers are increasingly part of networks of practice (NoP) [23]. These networks not only help professionals create and grow their social relationships, but also learn and share technical knowledge. The cross-organizational or field-level embeddedness of engineers in technical work practices, enabled by NoPs, has not as yet been examined in-depth.

Fourth and finally, ethnographic and other field study approaches have proven particularly valuable in uncovering and documenting different **engineering cultures**, including patterned variations in school versus work settings, across disciplines, within specific national/cultural contexts, etc. Different cultures of engineering are also frequently embedded within organizations and thus shape the participation and experiences of newcomers, including by discouraging certain groups from joining and staying in the field [24], while discouraging those who do persist from considering the broader social and ethical dimensions of their work [25]. We need to more deeply understand how such changes in engineering work are reshaping historically predominant cultures of engineering, and how engineers are responding to such changes – perhaps even by resisting cultures that do not resonate with them. Innovations in ethnographic methods remain well suited to investigating such dynamics.

New Methods

This research project is designed to be exploratory both in terms of the domain and topics we address and the methods we use. We wish to study work practices that are increasingly distributed, abstract, and hidden under layers of digitization. We need methods that can help us identify, gain access to, and analyze a wider variety of data sources. Further, we need more nimble ways to study practices given the pace of change in the field, as well as perennial issues of **access to organizations** [26]. The issue of access has been exacerbated in recent years due to many factors, including corporate concerns about protecting intellectual property, maintaining competitive advantage through proprietary business strategies, seeking to avoid reputational damage to the firm (e.g., from unflattering study findings), and minimizing costs related to employee participation (e.g., as subjects in research studies) with an uncertain value proposition. Research method innovations are needed to reduce barriers to access, minimize risks and costs to participants, and more quickly generate actionable insights for partner firms.

Given the preceding discussion of trends and challenges, we plan to carry out and investigate the efficacy of multi-institutional, multi-sites field research using novel methods such as agile ethnography, trace ethnography, and network ethnography. These methods are new and evolving, and thus have scarcely been used to study engineering practice. Yet they appear very promising given their potential to generate research findings much more rapidly and with a

greater focus on specific problems and questions. Indeed, such methods have started to gain traction in industry precisely due to such advantages, especially in software engineering and related fields where much work is already very digital and distributed in character [27]. We now turn to three more specific approaches proposed for this study.

Agile Ethnography: Whereas the broader lens of ethnography focuses largely on the study of culture across diverse settings, agile ethnography looks more specifically at what happens in workplaces [28, p. 1]. Unlike ethnography that is highly open-ended in its approach, agile ethnography takes a more formal and planned approach to data collection and analysis. As Borkovich stated, agile ethnography is "encapsulated by the constraints of time and access; the boundaries of a facility, department or discipline; the interchangeable, overlapping and cross-cutting cultural groups; and the researcher's limited period of performance – hence, the name, 'agile'" [28, p. 4]. The advantage of this approach is that it is more responsive to the business needs of companies that often require a faster turnaround, especially as compared to more traditional ethnographic methods that typically require significant time and resource investments. Balancing speed of research with empirical quality is something that agile ethnography has specifically focused on. Advocates explain that practitioners of this methodology examine and re-examine the data they collect, and carefully consider their analyses to make certain they correctly understand relationships and that participants understand the position of the ethnographer. However, they also acknowledge that agile ethnography may require more preliminary groundwork, including as related to research design, verification of the environment for study, selection of participants, collection of data, analysis of data, scrutiny of data, and writing of study [29, pp. 52-59]. Relationships with participants is another key consideration as the approach is intrusive. Thus, as in other types of studies, researchers are advised to respect the study setting, abide by ethical guidelines, and diligently carry out each recommended step in the research process [28-30].

Trace Ethnography: Marcus describes trace ethnography as a research method that focuses on several locations or vantage points [31, p. 95], in contrast to traditional ethnography that relies on a single perspective – namely that of the ethnographer. Hasu refers to trace ethnography as an "ethnography of change" [32, p. 90] that serves to understand the "invisible work" that takes place in organizations and is not always explicit in organizational documents. Geiger & Ribes present the technique in yet more depth, writing that it "combines the richness of participant-observation with the wealth of data in logs so as to reconstruct patterns and practices of users in distributed sociotechnical systems" [33, p. 1]. They add that this type of ethnography is guided by two key concepts: "First, documentary traces abound in today's technological systems, logging specific actions taken by uniquely identifiable individuals with very fine levels of granularity" [33, p. 1]. Further: "The second fundamental principle of trace ethnography is that, explicitly or implicitly, documentary traces are the primary mechanism in which users themselves know their distributed communities and act within them" [33, p. 1]. Traces are thus the steps individuals take in the world, and those steps are how people understand their place in the world [33, p. 1]. For these scholars, digital traces thus provide a kind of depth and detail that helps enable a deeper understanding of a focal setting, culture, topic, problem, etc.

Network Ethnography: Scholars have portrayed network ethnography as a multifaceted, adept approach crafted specifically to understand connections and relationships. Berthod, Grothe-

Hammer, & Sydow explore this subtype by asking: "How – and toward what ends – can we combine rich ethnographic data with the structural clarity of [social network analysis] at the level of whole networks?" [34, p. 300]. They argue that there is a scarcity of practice-focused scholarly inquiry into networks, and argue that this shortage can be remedied via the use of mixed methods study designs [34, p. 300]. They outline the steps involved in the conduct of this type of research: look at area to be studied, collect data, assess the information, get a basic look at the network in question, and take stock of the behaviors that explain the occurrences found during research [34, pp. 311-314]. In short, what they describe is an ethnography that looks at connections rather than just cultural practices. Writing about the physical education sphere, Sperka & Enright examine the utility and pitfalls of the technique and encourage other researchers to consider using it for their own studies, stating: "In our case, network ethnography produced knowledge differently and produced different knowledge about the outsourcing of HPE curricular work to external providers" [35, p. 178]. They add: "By employing Internet searches, we were able to build and research a field site that was not spatially bound and contribute new knowledge to the field" [35 p. 178]. These scholars show that network ethnography provides a way to investigate links between people and groups and answer questions uniquely related to those same connections.

Research Plan Overview

Table 1 provides a preliminary list of study sites for this project, including the primary research approach, and anticipated topical focus. The research plan for this project will involve a series of overlapping data collection and analysis phases, allowing the research team to iteratively use emerging insights to improve and enhance the study and synthesize results across study sites. The project will launch in Spring 2020 with intensive planning as well as preliminary data collection at one or more sites. Data collection and analysis will continue through Summer 2021. During the second and final project year (2021), attention will shift toward synthesizing and disseminating findings via papers and at least two workshops.

Table 1. Summary of Field Sites, Research Approaches, and Topics

	Investigator (Affiliation)		
	Jesiek (Purdue)	*Johri (GMU)*	*Brozina (YSU)*
Partner Organization	"Mfg Co."	"Global Co."	"Food Co."
Industry Sector	Aerospace	Multiple – AI, IoT	Supply Chain
Specific Study Context	Engineering Team Cross-Functional Collaboration	Global Collaboration US-India	National Collaboration
Research Approach(es)	Agile Ethnography	Trace/Network	Agile/Trace/Network
Topical/Thematic Focus	Alignment of work across different groups (including boundary-spanning, diversity, aligned use of digital data)	Incorporation of AI into applications across industries	Alignment of work through use of digital data and tools across different work groups

Conclusion

Designing courses and curricula to train future professionals requires a strong theoretical foundation in order to have the desired outcomes. As the context of work changes, it is

imperative that we revisit and review such foundations to ensure they are guiding us as desired. The proposed work introduced here aims to advance understanding of the engineering workplace by examining and comparing different empirical approaches within the ethnographic research paradigm. In addition to generating new knowledge about how to conduct research, it also has the potential to improve our understanding of the contemporary engineering workplace, such that the findings can be leveraged by educators and policymakers to improve the preparation of current and future technical professionals. Specifically, this project will use network, trace, and agile ethnographic methods to study work practices, while addressing the following research challenges: 1) alignment of new data collection and analysis approaches with emerging research topics and site access constraints, 2) managing, archiving, and sharing multi-modal ethnographic data sets, and 3) exploring alternative approaches to writing up research findings (e.g., thematic versus narrative styles), including formats and styles that may prove more accessible and appealing to wider audiences (e.g., students, instructors, industry practitioners, and policymakers).

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References

[1] Stevens, R., Johri, A., & O'Connor, K. (2014). Professional engineering work. In A. Johri & B. Olds (Eds). *The Cambridge Handbook of Engineering Education Research* (pp. 119-139). New York, NY: Cambridge University Press.

[2] National Academy of Engineering (2005). *Educating the Engineer of 2020: Adapting Engineering Education to the New Century*. Washington, DC: National Academies Press.

[3] Stevens, R., O'Connor, K., & Garrison. L. (2005). Engineering student identities in the navigation of the undergraduate curriculum. In Proceedings of the ASEE Annual Conference and Exposition, Portland, OR, June 12-15.

[4] Stevens, R., O'Connor, K., Garrison, L., Jocuns, A., & Amos, D. (2008). Becoming an engineer: Toward a three dimensional view of engineering learning. *Journal of Engineering Education, 97*(3): 355-368.

[5] Barnes, L. B. (1960). *Organizational systems and engineering groups*. Boston, MA: Harvard Business School.

[6] Youngman, M., Oxtoby, R., Monk, J. D., & Heywood, J. (1978). *Analysing jobs*. Farnborough, Hampshire, UK: Gower Press.

[7] Bucciarelli, L. L. (1988). An ethnographic perspective on engineering design. *Design Studies, 9*(3), 159-168.

[8] Bucciarelli, L.L. (1994). *Designing Engineers*. Cambridge MA: MIT Press.

[9] Davis, M. (1998). *Thinking like an engineer: Studies in the ethics of a profession.* Oxford, UK: Oxford University Press.

[10] Downey, G. L. (1998). *The machine in me: An anthropologist sits among computer engineers.* New York and London: Routledge.

[11] Henderson, K. (1991). Flexible sketches and inflexible data bases: Visual communication, conscription devices, and boundary objects in design engineering. *Science, Technology, & Human Values, 16*(4): 448-473.
[12] Henderson, K. (1999). *On line and on paper: Visual representations, visual culture and computer graphics in design engineering*. Cambridge, MA: MIT Press.
[13] Kunda, G. (1992). *Engineering culture: Control and commitment in a high-tech corporation*. Philadelphia, PA: Temple University Press.
[14] Williams, B. (2016). Engineering Practice as an Emerging Field of Inquiry: A Historical Overview. *Proceedings of the 2016 ASEE Annual Conference and Exposition,* New Orleans, Louisiana, June 26-29.
[15] Brunhaver, S., Jesiek, B., Strong, A. C., Korte, R., & Stevens, R. (2018). Research on Engineering Practice: Catalyzing a Scholarly Community. *Proceedings of IEEE Frontiers in Education Conference*, pg. 1-4.
[16] Johri, A., & Olds, B. (Eds.) (2014). *Cambridge Handbook of Engineering Education Research*. Cambridge University Press, New York, NY.
[17] Alshenqeeti, H. (2014). Interviewing as a data collection method: A critical review. *English Linguistics Research*, 3(1): 39-45.
[18] Boland, R., Lyytinen, K., & Yoo, Y. (2007). Wakes of innovation in project networks: The Case of digital 3-D representations in architecture, engineering, and construction. *Organization Science*, 18(4): 631-647.
[19] Yoo, Y., Lyytinen, K. J., Boland, R. J., & Berente, N. (2010). The next wave of digital innovation: Opportunities and challenges: A Report on the Research Workshop 'Digital Challenges in Innovation Research' (June 8, 2010). Available at http://ssrn.com/abstract=1622170
[20] Zussman, R. (1985). *Mechanics of the middle class: Work and politics among American engineers*. Berkeley, CA: University of California Press.
[21] Downey, G. L., Lucena, J. C., Moskal, B. M., Parkhurst, R., Bigley, T., Hays, C., Jesiek, B. K., Kelly, L., Miller, J., Ruff, S., Lehr, J. L., & Nichols-Belo, A. (2006). The globally competent engineer: Working effectively with people who define problems differently. *Journal of Engineering Education, 95*(2): 107-122.
[22] Irani, L., & Silberman, M. (2013). Turkopticon: Interrupting worker invisibility in amazon mechanical turk. *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 611-620), April 27-May 2.
[23] Wasko, M. M., & Faraj, S. (2005). Why should I share? Examining social capital and knowledge contribution in electronic networks of practice. *MIS Quarterly, 29*(1): 35-57.
[24] National Academy of Engineering. (2008). *Changing the Conversation: Messages for Improving Public Understanding of Engineering*. Washington, DC: National Academies Press.
[25] Cech, E. (2014). Culture of disengagement in engineering education? *Science, Technology, and Human Values, 39*(1): 42-72.
[26] Stevens, R., & Vinson, A. (2016). Institutional obstacles to ethnographic observation in engineering industry. In Proceedings of the 2016 ASEE Annual Conference and Exposition. New Orleans, Louisiana, June 26-29.
[27] Sharp, H., Dittrich, Y., & De Souza, C. (2016). The role of ethnographic studies in empirical software engineering. *IEEE Transactions on Software Engineering, 42*(8): 786-804.

[28] Borkovich, D. J. (2012). Agile ethnography: A qualitative methodology for the 21st century. *CIS Convergence Journal, 1*(1): 1-20.
[29] Borkovich, D. J., & Skovira, R. J. (2018). Agile ethnography: Interpreting organizational cultures in the information age. *Journal of Ethnographic & Qualitative Research, 13*(1): 46-61.
[30] Mara, A. F., Potts, L., & Bartocci, G. (2013). The ethics of agile ethnography. In Proceedings of the 31st ACM International Conference on Design of Communication (pp. 101-106), Greenville, NC, September 30-October 1.
[31] Marcus, G. E. (1995). Ethnography in/of the world system: The emergence of multi-sited ethnography. *Annual review of anthropology, 24*(1): 95-117.
[32] Hasu, M. (2005). In search of sensitive ethnography of change: Tracing the invisible handoffs from technology developers to users. *Mind, Culture, and Activity, 12*(2): 90-112.
[33] Geiger, R. S., & Ribes, D. (2011). Trace ethnography: Following coordination through documentary practices. In Proceedings of the 44th Hawaii International Conference on System Sciences, January 4-7.
[34] Berthod, O., Grothe-Hammer, M., & Sydow, J. (2017). Network ethnography: A mixed-method approach for the study of practices in interorganizational settings. *Organizational Research Methods, 20*(2): 299-323.
[35] Sperka, L., & Enright, E. (2019). Network ethnography applied: Understanding the evolving health and physical education knowledge landscape. *Sport, Education and Society, 24*(2): 168-181.