ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37193

Understanding the Situated Workplace Practices and Habits of Engineers Using Agile Ethnography

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Introduction

This methods paper describes the application of and insights gained from using aspects of an emerging methodology, agile ethnography, to study engineers working in practice. Research has suggested that there is a misalignment between what is taught in engineering school and the types of work that engineers do in practice [1]. Little is known about the types of engineering work that are conducted in practice [2], [3]. In order to best prepare engineering graduates to meet the demands of the engineering workforce, students should be taught the types of knowledge and problem-solving strategies that are commonly used by practicing engineers. By teaching students the problem-solving strategies that are used by their professional counterparts, the gap between what students are taught in school and what is expected of them in the workplace may be lessened.

The purpose of this paper is to describe how agile ethnography [4], [5] was successfully used in our research project to examine workplace literacy practices and habits of mind employed by eight engineers in their workplaces over a period of three years. The overarching purpose of the project was to develop models of disciplinary literacy instruction [6] and habits of mind [7] in engineering, both of which are potential methods for teaching students the knowledge, skills, and strategies that may prepare them for an engineering career. Disciplinary literacy instruction teaches students the ways that practitioners use literacy practices when reading, writing, interpreting, and evaluating discipline-specific information [8]. Habits of mind are the intelligent behaviors that guide how professionals respond when faced with situations of uncertainty [9]. By understanding how engineers use disciplinary literacy practices and habits of mind in the workplace, models for student instruction can be developed. These instructional practices can be used to support students' use of authentic engineering practices and ways of thinking that will support them in the classroom and in their future workplaces. Findings about the disciplinary practices and habits of mind of the eight engineers are presented in previous publications by the authors (e.g., [10]–[12]).

This methods paper adds to the literature on emerging approaches to investigating engineering workplace practice [13] by providing new insights gained about the challenges and perceived benefits of using elements of the agile ethnographic approach. The challenges that we experienced in doing this work included issues of organizational access to the engineering companies; negotiating the time and location of data collection with each of the engineers; managing logistics when on-site; and maintaining the accessibility of the data review process for the engineers. The benefits we perceived from conducting this work included the generation of a rich, detailed dataset; the knowledge gained about the feasibility of conducting research with engineers at their workplaces; and building relationships between the research team's university and the companies at which the engineers worked. These insights can inform how future studies of engineering practice are conducted and provide considerations for researchers aiming to conduct similar work in the future.

Background: Approaches to in-situ observational research

Traditional ethnographic approaches originated from research in anthropology and sociology (e.g., [14], [15]) exploring cultural groups through participant observation. These approaches require long-term, extensive fieldwork to understand the day-to-day lives, patterns, behaviors, beliefs, and values of a culture-sharing group [16], [17]. Ethnography has been considered an "emerging" methodology in engineering education research [18, p. 86] as there are limited studies that have employed these methods. Two notable examples of ethnographies in engineering education, both situated in academic contexts, include Foor, Walden, and Trytten [19] and Stevens et al [20]. Foor et al [19] conducted an "ethnography of the particular" [19, p. 104] in which one individual student's experiences were studied to demonstrate the importance of amplifying student voices that may be otherwise overlooked in engineering education. Stevens et al [20] conducted a four-year study of engineering students throughout their time at university to generate a framework for "becoming an engineer" [20, p. 355]. Ethnographic approaches have also been used in engineering education research to understand the nature of engineering practice. However, the number of these studies is limited [13]. As noted by Jesiek [13], the majority of these studies have employed field study methods in order to understand work culture, organization, and workplace practices. Due to the fast-paced, multi-modal, and distributed nature of today's engineering work environments, traditional long-term ethnographies may not be appropriate for understanding the work of engineers. New ethnographic approaches, such *agile ethnography*, may therefore be necessary for understanding engineering work [13].

Agile ethnography is an emerging ethnographic approach that is useful for participant observation in 21st-century workplace contexts, characterized by an agile relationship between the researcher, the environment, and the data collection process [4], [5]. The intent of this approach is to understand the norms, values, practices, and activities that exist within the fast-paced environment of businesses. Agile ethnography enables a researcher to be adaptable to rapidly changing situations that occur in a business environment, such as changes in personnel, schedules, or means of access [5]. The researcher must flexibly move between groups of people, events they may attend, and locations within the company without disrupting the research process. In addition, this method requires agility between the researcher and the workplace environment. The researcher must be able to be "thrown into a situation and [be] able to adapt in a flexible manner" [5, p. 50]. They must adopt a results-oriented mindset that allows them to navigate business and organizational environments with fluidity and efficiency. This need mediates the importance of the relatively short time spent in the field in these agile environments, compared to traditional ethnographies, which can span several years [13]. Workplace environments operate on fast-paced timelines to meet the needs of clients, industry sponsors, or government agencies. Agile methods allow for data to be collected, analyzed, and disseminated efficiently so that the workplace community can make timely, informed decisions from the research results. Throughout this process, the researcher must also build trust with participants during the short time frame. Traditional ethnographic approaches require the researcher to spend an extensive amount of time in the field to build trust with the community [5]. The agile ethnographic approach often accomplishes this through having an "insider" status [5, p. 49] into the company, which reduces the amount of time needed for the researcher to spend in the field. The researcher may be familiar with the workplace or have connections into the company, such as from prior employment status [5].

Agile ethnographic approaches also use data generation methods that are similar to those used in traditional ethnography, such as participant observations, interviews, and collection of artifacts [5]. To maintain the same level of credibility, accuracy, and transferability of qualitative findings as traditional ethnographic methods, the researcher must be proactive in developing a research plan that allows them to generate rich, detailed ethnographic data in a short timeframe. Triangulation methods, such as member checking and comparing data sources, can provide confidence in the credibility of results obtained from agile ethnographic methods [4].

Study Methods

Participants

This work generated qualitative data with eight practicing engineers over a period of three years. The engineers were purposefully selected for participation to represent a variety of engineering disciplines, workplace roles, and types of organizations (Table 1). Each engineer was formally trained in one of four engineering disciplines (i.e., civil/environmental, mechanical/aerospace, electrical/computer, and chemical/biological) and was employed at one of eight different engineering companies. Table 1 provides a summary of the engineer participants, including their discipline, role, organizational focus, and their self-identified gender.

Table 1: Overview of the eight practicing engineers that participated in the disciplinary literacy and habits of mind studies.

Engineering discipline	Work role	Organizational focus and size	Engineer gender
Chemical/Biological	Operations management	Products for human consumption; international; for profit	Female
Chemical/Biological	Process design and applications	Products for human consumption; regional/national; for profit	Female
Civil/Environmental	Engineering management and project oversight	Municipality; local/city; not for profit	Male
Civil/Environmental	Research	Environmental research; international; not for profit	Female
Electrical/Computer	Software development	Data acquisition and monitoring; international; for profit	Male

Electrical/Computer	Hardware design and testing	Control systems and software; regional/national; for profit	Male
Mechanical/Aerospace	Design	Mechanical systems; international; for profit	Male
Mechanical/Aerospace	Management	Aerospace industry; national (government contractor); for profit	Female

Data generation

Researchers generated data with the eight engineer participants on-site at each engineering organization. Exceptions to this approach occurred during the COVID-19 pandemic, in which engineers were observed remotely using video-conferencing software. Each engineer participated in the study for at least six months. During this time, a member of the research team conducted two-hour observations of the engineer participants at their workplace twice per month. Each engineer was also asked to keep a written log of the texts that they read and wrote during times when the researcher was not observing them. After each observation session, interview and think-aloud protocols were developed by the team using the observational data and log entries. Once per month, a research team member used these protocols to conduct two-hour semi-structured interview and think-aloud sessions with each participant. Engineers were prompted to answer questions about the work they had performed and the texts they had written about in their logs. For the think-aloud, engineers were requested to bring one of the texts that they worked with during the observation sessions. They were prompted to retrospectively think out loud about their thought processes that they had used as they engaged with this text in the workplace.

Data analysis

Data from field notes taken during the observations and transcripts from the interview/think-aloud sessions were analyzed using qualitative coding procedures [21]. The constant-comparative analysis technique [22] was used to develop initial and focused codes for types of written texts that the engineers read or produced, cognitive frameworks that they used to interpret and evaluate information, and mental habits that they used when solving problems. Within-case and cross-case analyses [23] were conducted to identify and describe how literacy practices and habits of mind were used among engineers in the same discipline and across disciplines. Findings from these analyses are presented in other publications by the authors (e.g., [10]–[12]).

Comparison of study methods to agile ethnography

Ethnographic approaches to research are unique among qualitative research methodologies across several dimensions of inquiry, including the time spent by researchers in the field, the need for researchers to negotiate entry into the research space by building trust, the data generation methods used to gain detailed and descriptive data, and the overall purpose or intent

of the research. As shown in Table 2, the current work implemented several key elements of agile ethnography across these dimensions of inquiry.

Table 2: Comparison between traditional ethnographic methods, agile ethnographic methods, and the methods that were used in the present study.

Dimensions of inquiry	Traditional ethnography	Agile ethnography	Study methods
Time in the field	Prolonged data collection that can span multiple years [5], [17]	Short data generation timeline, e.g. 90 days, 120 days [4]	Six months of data generation per engineer; data generated with eight engineers over a three-year period
Building trust	Extensive time in the field needed to earn trust as a researcher [5]	The researcher is an "insider" who is familiar with the environment [5]	Recruitment done by a researcher who is also a professional engineer "insider"; researchers doing observations are also engineers
Data generation methods	Observations, interviews, artifacts [16]	Observations, interviews, artifacts [5]	Observations, interviews, think alouds, artifacts
Research intent	Understanding patterns, ideas, and beliefs of a culture-sharing group [16]	Understanding employee group dynamics, body language, mannerisms, appearances, and work tasks performed [5]	Identifying and examining the disciplinary literacy practices and habits of mind of engineers working in practice

First, this study employed a short *time in the field* with each engineer compared to traditional ethnography. The data collection time for this work occurred over six months with each engineer with observations occurring twice per month for two hours per session and interview/think-alouds occurring once per month for up to two hours. In traditional ethnographies, the researcher engages in sustained observations of the daily lives of the culture-sharing group [5], [16]. However, the nature of the engineering workplace environment required the researchers to be mindful of the limitations associated with observing an engineer while at work. The researchers did not want to be overly intrusive or impact the engineers' or their coworkers' productivity. This required that the researchers use agile methods to collect data efficiently and in a timely manner. In addition, the purpose of this work was to understand specific culturally embedded practices (i.e., disciplinary literacy and habits of mind) rather than the culture of the engineering

workplace as a whole. While the choice to conduct this work at predetermined times and locations may not have provided the depth of insight that traditional ethnographic approaches offer, strategically recruiting different types of engineers and observing them at their convenience allowed the researchers to build relationships of trust and confidence with the engineers and their managers and ensured that data was collected in timely manner. The entire data collection process across all eight engineers spanned three years, but the time that each engineer participated was relatively short and allowed the researchers to gather data efficiently while effectively meeting the research outcomes.

Next, the researchers in this study *built trust* with the engineers and company representatives through ongoing conversations and meetings during the recruitment process and over time through data generation. The recruitment phase was conducted by a researcher who is also a professional engineer with knowledge about the inner workings of engineering firms. In addition, the researchers who conducted the on-site observations were also engineers themselves.

This study also used *data generation methods* that are in alignment with both traditional and agile ethnographic approaches. This included conducting participant observations on-site at the engineering workplaces, facilitating interviews and think-alouds with the engineer participants, and obtaining artifacts from the engineers.

Last, the *intent* of this research was to identify the disciplinary literacy practices and habits of mind of practicing engineers through immersive, in situ observation and in-depth interviews. This study leveraged both the goals of traditional ethnography and agile ethnography to understand these practices and habits by examining the patterns and beliefs of a culture-sharing group (traditional) within a workplace context (agile). While agile ethnographies are typically conducted to understand the culture of a workplace as a whole [4], [5], this work used elements of the agile ethnographic method (i.e., researcher flexibility and ability to readily adapt to changing situations) to understand specific culturally-embedded practices (i.e., disciplinary literacy and habits of mind) that occurred in a workplace context. Using agile methods enabled the researchers to be more adaptable to the fast-paced nature of the engineering workplace environment than would be feasible in a traditional ethnographic approach. The following sub-sections describe in detail how elements of agile ethnographic methods were used for this work.

Adaptability to rapidly-changing situations

Agile ethnography researchers to be flexible and adaptable to situations that may change rapidly or spontaneously [9], [10]. When conducting the observations on-site, it was necessary for the researchers to adapt to the fast-paced environment of the engineers' workplaces. In their field notes, the researchers captured all of the different textual genres that the engineers read and wrote; the conversations that the engineers had with colleagues as they discussed problems and solutions; and contextualizing information about the environment and situations that were observed. This process required that the researchers were quick to capture information as the engineers reviewed it on their computer screen or as they had short conversations with coworkers that passed by their office. The ability to remain agile was essential for the researchers to capture important details in their field notes for later analysis.

Additionally, the researcher needed to be flexible to changes in the engineers' focus in the moment. For example, the engineer may have been working independently in their office, but then needed to refocus as they attended a meeting. Informal meetings occurred with colleagues as they passed by each other in the hallway or stopping by their office to ask a question. Formal meetings occurred in dedicated conference room spaces or group work areas and included both focused points of discussion and conversations that trailed into different topics. The researcher had to quickly adapt to naturally these changing environments and conversations as the engineer progressed throughout their day.

The researcher was also responsive to changing workplace events as they unfolded. On some days, the researcher observed the engineer working at their computer in their office for the entire two-hour observation session. Other days, the engineer would be called to work on a problem in a completely different area of the company, such as outside of the building or on the production floor. The researcher needed to be able to quickly adapt to the changing scenario and focus the content of their field notes to capture the new context of the situation and details about the people, environment, and conversations that were occurring in real-time.

Flexibility in scheduling

The researcher also needed to be flexible about changes in scheduling the meeting times for observations and interview/think-alouds. On occasion, an engineer would contact the researcher to let them know they would not be able to be observed or interviewed on the day they had scheduled. They may have had an emergency meeting scheduled that the researcher was not permitted to attend, the engineer may have been called to work at a different work site, or the engineer was attending a professional development workshop in a different city. The engineer and researcher would then work together to reschedule the missed day and ensure that the subsequent sessions were scheduled in accordance with the data collection timeline.

The researcher also remained flexible when choosing dates and times to conduct the two-hour observations. On some days, the engineer would plan to attend meetings in which they would be discussing secret or propriety information that was not appropriate for the researcher to observe. The researcher and engineer would schedule the observation window around these types of meetings, even if it meant deviating from the regular meetings that had been agreed upon. Remaining agile enabled the researcher to accommodate these types of needs in the engineers' work schedules while also adhering to the research timeline and collecting data promptly and efficiently.

Flexibility in modality

The agile ethnographic method also allowed for the researcher to be responsive to changes in the engineers' work environments during the shift to remote work during the COVID-19 pandemic. Rather than needing to "[stop] the fieldwork to return to the drawing board" [4, p. 10] during the uncertain times of the early stages of the pandemic, the researcher remained agile and adjusted to new modes of observation and interviewing. The researcher adapted the mode of observation and interviewing/think-alouds by using video conferencing software and screen-sharing tools to observe and interview the engineers remotely. Engineers that were observed remotely also had

their preference of work modality. For example, one engineer worked mostly from home on observation days and would share their screen while they conducted their work. Another engineer would follow this same approach, but on some days would be working in the office while the researcher observed remotely. The engineer brought their laptop around their workplace with them with their camera and screen-sharing turned on as the researcher observed them. Maintaining this type of flexibility when observing and interviewing the engineers was essential to sustaining the strong relationships that were built between the researchers and the engineers and in ensuring efficient data collection.

Insights gained from conducting workplace ethnography

The implications of this work are twofold. First, the findings of the disciplinary literacy and habits of mind study provide valuable insights into the nature of engineering practice, including the types of problems that engineers solve and how they work with others to develop solutions. Using aspects of agile ethnographic methods, this study yielded important understandings about the different types of texts that engineers read and wrote, the cognitive frameworks that they used, and the mental habits they employed when faced with difficult situations [10]–[12]. Insights from this work can inform K-12 and undergraduate engineering curriculum development efforts that seek to teach students disciplinary practices and mindful habits that can guide their thinking as they solve problems and work with others. Second, this work provides insights about the challenges and benefits of using elements of agile ethnography with practicing engineers at their workplaces and reveals that work of this nature is possible amidst various challenges.

Challenges of conducting this work

Organizational access

Organizational access has been called one of the "perennial issues" of the observational study of workplace practices. Issues of research-related access to professional organizations, particularly for-profit companies, have been linked to organizational desires to protect intellectual property and proprietary business strategies, avoid "bad press" or more permanent damage to an organization's image or reputation based on study findings, and reduce organizational costs, in terms of time and productivity, of employee participation [13, p. 3]. In this work, challenges related to organizational access occurred during initial *participant recruitment* and when *negotiating entry* into the research space.

Participant Recruitment. One of the researchers who is also a professional engineer with industry experience undertook the recruitment of the participant engineers. In this discussion, *participant recruitment* includes the identification of a qualified engineer willing to participate in the study. Due to the need for researchers to travel to the companies three times per month for data generation activities, local organizations (or organizations with locally distributed workplaces) were prioritized for recruitment. To ensure that findings were widely representative of authentic engineering work and to broaden recruitment prospects, both not-for-profit and for-profit organizations that used the services of engineers or employed engineers were considered as potential recruitment sites.

Recruitment activities began using a "top down" approach at the organizational level as the researcher directly contacted personnel within local engineering organizations. Depending on the size and scope of the organization, the researcher contacted a variety of organizational members (e.g., education outreach coordinators, senior management, and HR personnel) via email and phone messages. Typically, several rounds of communication were needed to achieve agreement on the organization's ability and willingness to participate. In some cases, in-person meetings and/or presentations were used to communicate the research purpose, scope, methods and to help them calculate the "cost" and "risk" of participation to their organization. In these cases, organizations provided potential engineer participants and the researcher then contacted the engineer to gauge their interest in participating.

To realize new recruitment potential, the researcher then used a "bottom up" approach by employing snowball sampling of current and former professional colleagues within local engineering industry and at the university. The researcher identified disciplinary engineers working locally who were both qualified and interested in participating. In these cases, the researcher worked directly with the engineers to identify the organizational agents who needed to be contacted to discuss participation. In one instance, the researcher was requested to attend a seminar sponsored by a local organization in order to get access to its president and "pitch" the participation of one of their engineers in the study. Overall, engineers who considered participating appeared excited about the idea of the study. Engineers expressed concerns about whether their organization would allow them to participate, how participation might impact their productivity, and the level of flexibility when scheduling the data generation sessions. One participant, for example, requested that they schedule interview/think-aloud sessions after work hours to lessen the impact of participation on their work.

Negotiating entry. Researcher entry into the organization also had to be negotiated. In this discussion, *negotiating entry* includes developing satisfactory procedures and gaining the required level of trust with organizational leaders for them to approve an engineer's participation. Organizational leaders in our study were often concerned about inadvertent collection and dissemination of intellectual property, propriety information, or trade secrets [13], [24]. In addition, engineering managers expressed concerns about whether the research process would occupy too much time and diminish the engineer's productivity. They were also concerned about how the presence of a researcher might encumber team communication or the productivity of other employees that relied on the engineer. Others were concerned about the safety of the researchers and willingness to adopt appropriate organizational policies, such as on a manufacturing floor.

To abate these concerns, researchers often developed organization-specific procedures, such as wearing production garments and shoe coverings while on site, entering through a particular door, leaving mobile devices at the front desk, or being escorted while on site. Researchers also worked to build and maintain the trust of organizational leaders by drafting non-disclosure agreements (NDAs) and presenting them to the organizations as a proactive measure of good faith. Researchers made data available to both the engineer participants and organizational leaders, which provided them confidence that proprietary data would not be permanently captured, analyzed, or disseminated. Meetings (as many as necessary) were held between the researchers and the organizational stakeholders to discuss all aspects of the research plan,

including the intent, procedures, and potential benefits to the company, to understand the nuanced requirements of each workplace environment, and to present informed consent documentation to the engineer. These meetings helped build a layer of trust between the researchers, the organizational leaders, and the participants, and often resulted in an organization being willing to facilitate the research.

Time and location of data collection

The researchers aimed to set up recurring times for the on-site two-hour observation sessions (e.g., Tuesdays from 9 to 11 am). For some of the engineers, this scheduling worked well. Other engineers preferred to schedule sessions on an ad-hoc basis because their schedules were more prone to last-minute changes. There were also instances where the engineer needed to reschedule their observation due to unanticipated meetings, site visits, or off-site testing. In addition, some engineers preferred to conduct the interview and think-aloud sessions after work hours instead of during their work time. They did not want to lose their productivity time at work or did not feel it was appropriate to take time from work to conduct the interviews. The researchers needed to be flexible in their own workday to accommodate these types of requests from the engineers and offer an alternative time and location for holding these sessions (e.g., in a room on the university campus in the evenings). Challenges with scheduling access to the companies and engineers themselves required the researchers to adapt the data collection schedule to be considerate of the engineers' needs as they met the demands of their job while also participating in the study.

Logistical considerations on-site

Another challenge was managing the logistics of data generation while at the companies. The engineers worked on many different tasks during the observation sessions. Sometimes an engineer would remain at their computer for the entire duration of the observation. Other times, they would move to a colleague's office or to a meeting room and back to their computer again. In other instances, the engineer was working on the production floor of the plant and only went to their computer to cross-reference a specification sheet or schematic. In any of these situations, the researcher needed to be able to quickly capture details about the engineer's work, such as the program they were using and for what purpose. Additionally, the engineers often switched between documents and programs rapidly in order to complete tasks or find information. The researcher had to be able to quickly capture the information about what the engineer was working on in their field notes with sufficient details and context. The observation sessions also required the researcher to use a high degree of judgement about the information they documented in their field notes. The engineers often worked with sensitive data or propriety information and the researcher needed to ensure that they captured enough detail in their notes about the engineer's task without collecting any sensitive information.

Accessibility of data review

Upon completion of their participation in the study (i.e., six months), the engineers and their immediate supervisors were invited to review all the data that the research team had collected with them. This request for review was to remove proprietary or confidential information that was inadvertently collected and to give the participants and companies control over what data

would be kept and analyzed. Data included the typed versions of the field notes taken during the observations, transcripts from the interview and think-aloud sessions, photographs of the literacy logs that they kept, video recordings taken during the think-aloud sessions, and any photographs that were taken at the workplace or provided by the engineers. Both the engineers and their supervisors had the opportunity to request that any information be deleted from the research team's records. The research team aimed to provide ample time and easy access for this process.

Engineers and their supervisors were invited as collaborators on Box, a secure file-sharing platform, to review folders containing their data. Data was first opened to the engineers. This strategy enabled the engineers to redact any personal data that they, in retrospect, did not want their supervisor to see. Once the engineers had reviewed their data, the folder was then opened to the supervisor. Some engineers and supervisors thoroughly reviewed the information in their data files and left specific notes about phrases or terminology to remove. Some supervisors declined to review their files and instead trusted the engineer's review of the data. In some cases, the supervisors or engineers required a different mode of access to review their files on Box due to restrictions in their ability to access the platform on their work computers. In these instances, the researchers worked with the engineers to set up a time for the engineer to meet a researcher on the university campus and provide them with a computer.

Benefits of conducting this work

Generation of rich, detailed data

The efforts of this research resulted in a robust dataset that provided unique, firsthand insights into the workplace practices of eight engineers at eight different engineering companies. In total, the researchers conducted 12 two-hour observations of each of the engineers at their workplaces for a total of 96 observations across all eight engineers. The researchers held six two-hour long interview/think-aloud sessions with each engineer for a total of 48 interview/think-aloud sessions across all eight engineers. This substantial amount of data collected with each engineer provided rich, thick details about the nature of the engineers' work, their interactions with colleagues, and contextual information about their work environments. Additionally, this dataset was detailed and descriptive enough to be analyzed under two different frameworks exploring two different constructs. Initially, the data was gathered to learn about the disciplinary literacy practices of engineers (e.g., [10], [11]). The data was then re-examined to answer new research questions under a different framework to explore engineering habits of mind [12]. These results provide evidence that data obtained from practicing engineers using agile ethnographic methods can be valuable for understanding varying aspects of engineering practice.

Feasibility of learning about engineering practice

This work also demonstrates the feasibility of conducting ethnographic research in the engineering workplace. Ethnographic studies in engineering education are limited [18] and the lack of knowledge about the nature of engineering practice gained from qualitative methods can often be due to barriers to access [13], [24]. However, the work presented in this paper shows that using ethnographic methods to understand the nature of engineering practice is possible. Meeting challenges that were faced by persisting, maintaining flexibility, and having open

conversations with engineers and their companies allowed for the research team to build confidence in the project and trust with the participants. Going forward, using agile ethnographic methods may be a promising approach for future engineering education research endeavors.

University and industry relationship-building

Last, this work enabled the research team to develop relationships with eight different engineers at eight different companies. The researchers and engineers worked together closely through all phases of the research process, from recruitment to the conclusion of the engineers' participation. The team actively ensured that trust and confidence was built between the researchers, participants, and company managers or representatives. By building these relationships, the researchers were able to share information about the field of engineering education to the engineering companies that participated. Some companies indicated their excitement to contribute to improving engineering education using knowledge gained from practice. Additionally, some of the engineers themselves took a personal interest in participating in engineering education research. One engineer expressed interest in improving engineering education outcomes for women; two other engineers expressed interest in learning how to improve communication skills in engineering; and one engineer became interested in pursuing engineering education as a career field. These outcomes revealed that engineering professionals may have an interest in engineering education, and there are opportunities for collaboration between universities and engineering firms on the basis of improving the professional formation of 21st century engineers.

Conclusion

This work demonstrates an example of how agile ethnographic methods can be used to more deeply understand the work of engineering practitioners. This study shows that research conducted with engineers in the workplace is feasible despite challenges that may be faced, including gaining organizational access and negotiating time, location, and on-site logistics. Researchers should therefore be mindful of these potential challenges and the demands that this type of ethnographic work has for research teams. In spite of these challenges, the results of this work show that there are valuable benefits to collecting ethnographic data with practicing engineers at the workplace. From a rich, detailed qualitative data set, insights were gained about how engineering practitioners at eight different companies used disciplinary literacy practices and engineering habits of mind. Future work exploring the nature of engineering practice should consider using alternative ethnographic methods, such as agile ethnography, to conduct qualitative research with engineers in the workplace. These methods can allow researchers to gather the data necessary to bridge the gap between academia and practice while remaining flexible and agile to the fast-paced work environment of modern engineering firms.

Acknowledgements

This material is based upon work supported by the U.S. National Science Foundation under Award No. EEC 1664228. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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