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RESEARCH ARTICLE

Ethics as a rare bird: a challenge for situated studies of ethics in the engineering lab

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ABSTRACT

Engineering ethics cannot be reduced to the ethics of individual engineers but must be considered *in situ*, within the sociocultural and environmental contexts of a research or design project. We studied teams in academic engineering research laboratories and how they understood and practiced ethics in their own work. Problems arise for ethnographic methods for researching this aspect of engineering ethics; namely, voluntary ethics discussions rarely occurred in the lab. In our field site, we observed many spontaneous discussions, but engineering ethics issues were not among the topics discussed. Ethical decision-making seemed to be like a rare, shy species of bird, hard to spot, requiring methods to flush it out of hiding or attract it. We adapted structured interview and facilitated discussion protocols to accomplish this. Success was modest. The problem lies both in engineering culture and in the methodological difficulties in studying situated, distributed ethical deliberation and responsibility.

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Introduction

This is the story of a failed research project, the interesting phenomenon that failure disclosed, and two attempts to overcome that failure, to limited success. The original project was a cognitive ethnography of ethical reflection and decision-making in the engineering research laboratory. This project failed due to a phenomenon we are calling 'the Rare Bird Problem.' Spotting ethical activity in the lab turns out to be as difficult as observing a rare species of bird in nature with limited knowledge of its natural habits. In itself, this phenomenon represents an interesting discovery. It both poses significant methodological problems and contains important information about engineering as a field that is corroborated elsewhere.

The goal of the project was to understand the role that ethics actually plays in the everyday practice of engineering research, particularly the role that value judgments and ethical deliberation play in 'midstream' decision-making in the engineering lab, with the hopes of using such an understanding as a basis to improve the ethically responsible conduct of research as it progresses (on 'midstream' see Fisher, Mahajan, and Mitcham 2006). Our understanding of 'ethics' is broad, including not only narrow professional obligations

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but also broader obligations to society and the environment. In particular, we did not limit our understanding of ethics to narrow compliance with professional codes of ethics or more broadly to ethical principles; we see ethics as happening throughout the course of practice as various values become relevant to decision-making.

We began with a theoretical orientation and a methodological presupposition. First, engineering ethics cannot be simply reduced to the ethics of individual engineers, considered as independent, isolated agents. Instead, engineering ethics should be considered *in situ*, within the social, cultural, and environmental contexts of a research or design project team. In this study, our goal was to observed teams in academic engineering research laboratories and determined how they understood and practiced ethics in the context of their own work. Coming from the perspective of situated learning and distributed cognition, we are skeptical of the ecological validity of studies that investigate such complex cognitive-cultural processes in artificial environments, and we are even more suspicious of educational interventions that are not based on a solid understanding of the naturally (culturally) situated process itself (See Lave 1988; Cole 1996, 1999; Williams 2006). Thus, we presuppose that an adequate understanding of engineering ethics as it is practiced and any attempts to improve it must begin with the kind of research methods best suited to understanding such processes.

In some respects, this research project continues the long tradition of laboratory studies in science and technology studies (see Latour and Woolgar 1979; Galison 1987; Knorr Cetina 1995, 1999; Stephens and Lewis 2017), extending the focus from broadly *epistemic* questions about how knowledge is created (though those questions have often been given social and political answers), to broadly *ethical* and *social* questions about the ethical responsibility in research. These studies, like our study, pursue a broadly *ethnographic* approach to understanding the research lab; however, we have also been influenced by Ron Giere's and Nancy Nersessian's powerful critiques of standard laboratory studies methodology (Giere 2002; Giere and Moffatt 2003; Nersessian et al. 2003a). On their view, rather than dichotomize the cognitive and the social, one must learn to see how social processes are also cognitive processes. In this way, our work is more neatly situated in the tradition of *cognitive ethnography* than the tradition of laboratory studies (Hutchins 1995; Alač and Hutchins 2004; Nersessian et al. 2003b). Finally, we were inspired by the work of Erin Cech (2014) on the culture of disengagement in engineering to engage in a detailed study of the role of ethics and social issues in the culture of the engineering laboratory.

Our original research plan thus had three phases: First, we carried out a traditional ethnography of the engineering lab, to form a background understanding of the social structure and culture of the laboratory. Traditional ethnography by itself is not ideal for studying cognitive processes like ethical decision-making, however. Therefore, our second step was a *cognitive ethnography* of the ethical decision-making processes in the lab. Cognitive ethnography is a natural methodology for researching situated ethical decision-making, as it has proven to be an effective method for studying situated and distributed cognition in practice. Our third phase was to be an *intervention* in the laboratory aimed at modulating and improving the ethical decision-making process.

Unfortunately, we did not make it to the third phase of our original design, because of a crucial problem with the first two phases of our research plan. We found that voluntary ethics discussions rarely occurred in the engineering lab, making general and cognitive ethnography unworkable methods in this context. Our field site lab has an atmosphere that encourages free, spontaneous discussions among the members, and our participant-observer developed a working rapport with the lab and observed many instances of spontaneous discussion in the lab; nevertheless, engineering ethics issues were never among the observed discussion topics. Ethical decision-making seemed to be like a rare, shy species of bird, very hard to spot while just observing its environment. As noted, we call this the Rare Bird Problem.

The alternatives to waiting to see if the bird shows up are to pursue methods to flush it out or to specifically attract it. In other words, we need some sort of intervention to bring the bird and the observer together; however, the situation is unfortunate from our starting perspective, because it departs from the initial requirement of observing the bird in its natural environment and course of behavior, and because it blurs the distinction between observation and intervention. If the bird is rare enough, however, successfully studying it requires overcoming these problems.

Following out the analogy, we pursue two kinds of light intervention strategies to try to bring the observer and the phenomenon of ethical deliberation closer together. To flush ethical deliberation out, we pursued a structured interview protocol, adapted from an instrument more focused on intervention than observation, namely, Socio-Technical Integration Research (STIR) (Fisher and Schuurbiers 2013; Flipse, van der Sanden, and Osseweijer 2014; Fisher et al. 2015). While the STIR protocol is not itself an ethnographic approach, it *does* involve embedding a researcher in the laboratory. The protocol not only fits into the broader stream of laboratory studies approaches. While it is an interventional methodology, it is not a top-down intervention. Rather, it involves the researcher asking questions of the laboratory member that require the latter to better articulate their decision-making, as well as considering a larger number of options and values. We modified this protocol to be even less of an intervention than is standard, in light of the aims of the study.

To continue the metaphor, we attempted to attract ethical deliberation by inviting lab members to a facilitated discussion, adapted from the Toolbox Project workshop protocol (O'Rourke and Crowley 2013; O'Rourke et al. 2013). The Toolbox dialogs are neither an ethnographic protocol nor particularly a laboratory studies protocol, though it is typically applied to the members of a research lab, as in our case. Again, it is not a top-down intervention, but another way of requiring lab members to articulate their values and commitments. One benefit to the Toolbox model is that it is more directly social, involving a group discussion. One drawback is that it is less directly connected to practice.

Success in each case was modest. Ethical engagement in interviews remained vague and difficult to elicit, though the lab members were not indifferent to engineering ethics in general. During the facilitated discussion, lab members showed a somewhat narrow and rigid understanding of engineering ethics, a lack of understanding in the social dimensions of engineering ethics, and a tendency to shift ethical responsibilities to others. Based on these findings, we conclude that part of the fault is methodological – there remains a need for methodological innovation to study situated, distributed ethical understanding and decision-making in engineering practice and create engagement around ethical issues. Another aspect of the problem is related to engineering culture: explicitly discussing engineering ethics is not cultivated as a habit among engineering students, nor does the engineering profession make much room for engaging in shared decision-making about ethical aspects of team projects. More radical interventions may be necessary for the cultivation of responsible engineering.

Field site: the APR lab

The APR Lab[1] is a large engineering lab that conducts various research projects, mainly in materials and mechanical engineering, with approximately 70 members. Under the professor who directs the entire lab, there are a research professor, post-doctoral researchers, senior engineers, a lab manager, graduate students, and undergraduate students at the time of the observation. The lab members have diverse academic backgrounds, including material science, chemistry, bioengineering, and mechanical engineering. The cultural background of the lab members is also diverse, including many international students and students from different ethnic or cultural backgrounds. When we invited six core members of the lab who lead multiple projects and supervise undergraduate students to a discussion, four of the six members had an international background. We will discuss further below.

The lab consists of many team-like units. In some cases, a single team has more than one project; in other cases, multiple teams work on a single, large project. The hierarchical structure and function of the lab are in some respects like a small company. Experienced researchers like post-docs teach and guide student teams, acting as research advisors. Graduate students train undergraduate students on how to use necessary equipment and how to conduct experiments before letting them join the project team and generally act as project managers for those teams. Figure 1 shows a professional network in the lab, representing how members are related to each other in terms of their research projects. The dots represent specific members of the lab, and the lines between the dots represent the relation such as working together in the same research project, mentor-mentee relationship or collaborating for the related topics. The bigger dots represent people who have more connections and greater influence. This network map presented useful information in targeting informants and discussion participants.

The APR Lab is located in a science and engineering research building that is shared with many other research labs. The APR Lab is divided into several distinct spaces in the building. The Basic lab is located in the basement where newly joined undergraduate students are usually trained. The Clean lab, where products are created or tested, is located on an upper floor along with the Chemistry lab. There is an Open Area on a separate floor that post-doctoral researchers and graduate students share. Most students discuss their work with each other or seek help from their advisors there. The work environment in the lab is free and open to the members, and one of the unique features in this lab is that research meetings usually happen spontaneously, on the spot, rather than in a pre-arranged fashion. The diverse backgrounds of the members also contribute to these spontaneous discussions, because whenever one of the members faces a problem, he or she can always rely on a person who has expertise related to that problem.

(a) Dots indicate individual members, letters on dots indicate identification codes of members, and lines between dots indicate members that work together in the research project.

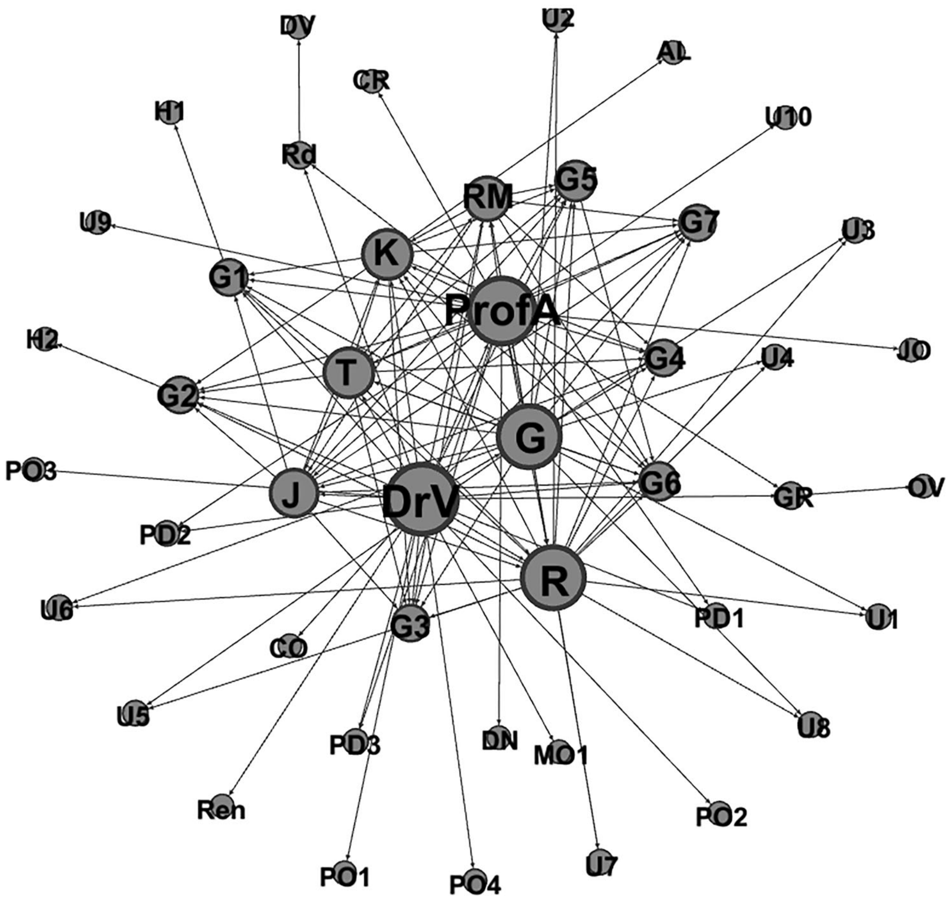

Figure 1. The professional network of the APR Lab members.

(b) Dot size indicates the degree of networking. Large dots in the central area represent members who work with many colleagues, usually participating in various research projects.
(c) This network map shows the working relationship among the lab members; highly networked members are usually experts and involved in many projects.

Initial methodology

Traditional ethnography

Ethnography is a richly qualitative field-research methodology centered on participant-observation of spontaneous social activities within an everyday cultural context (Ball and Ormerod 2000). Prototypical or traditional ethnographic methods include participant-observation, interviewing, and artifacts analysis. Field notes taken during participant-observation, video and audio recordings of observed phenomena, recordings and notes of interviews, photos and sketches of artifacts are all analyzed to capture the meanings that observed subjects share in the group. The result is often presented in descriptive

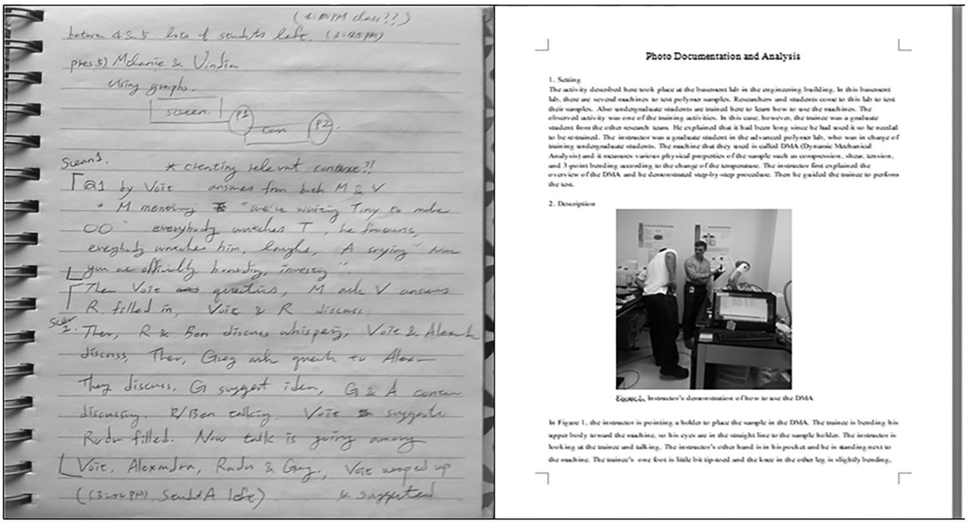

Figure 2. An example of the field note taken at the observation of the group seminar (left) and an example of the photo documentation of the training activity (right).

and narrative forms. Figure 2 shows an example of the field note and the photo documentation of the training activity at our field site. The left part of the figure shows a part of the field notes taken during an observation at our field site, and it includes a description and drawings of what people did during that activity and how they did it. The right part of the figure shows a part of the photo documentation that records one of the training activities. The photo documentation was created in a narrative form based on photos and the field notes.

Cognitive ethnography

Cognitive ethnography is a qualitative methodology suited to the study of cognitive processes, i.e. how people make decisions, process information, create meanings, or learn new things. Cognitive ethnography uses the same methods of traditional ethnography, such as observation, interview and artifact analysis, but combines them with the analytical techniques and theories of cognitive science, as well as relying more heavily on digital recording and analysis tools. Instead of focusing on the system of meanings that an observed group possesses – one of the central tasks of traditional ethnography – cognitive ethnography focuses on how members of an observed cultural group create those meanings (Williams 2006). Often, cognitive ethnography employs micro-scale analysis and digital technology to capture the occurrences of cognitive activities in detail and to analyze the mechanisms and processes of interpersonal, naturally-culturally situated and techno-socially distributed cognition (Alač and Hutchins 2004). Figure 3 shows an example of how we analyzed the video segment of another training activity at our field site. Unlike the narrative description of the photo documentation in Figure 2, this video analysis includes detailed descriptions with transcription of actual discourse at a micro-scale time frame, highlighting significant details with red circles and arrows, and the most

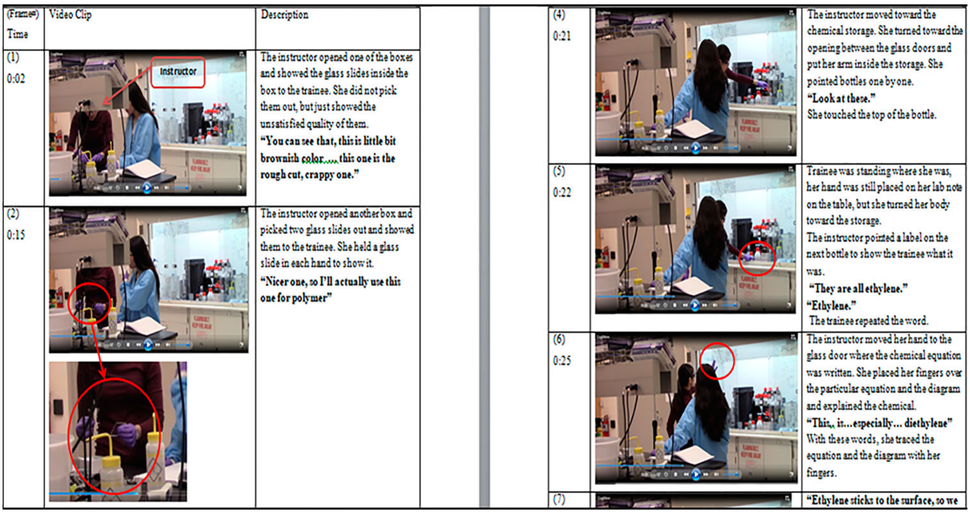

Figure 3. An example of cognitive ethnographic analysis of the video segment.

significant text in bold. The qualitative, observational, and descriptive attributes of cognitive ethnography are highly useful in the study of complex cognitive process of human activities. We used cognitive ethnography as a primary method to study engineering ethics in the engineering lab as a situated and distributed cognitive activity. The observation and analysis based on cognitive ethnography were conducted from the beginning of the data collection to the final data analysis.

Data collection and analysis

Data collection was done by one of the researchers over the course of three months, from late September to mid-December. This researcher has a background in science education and cognitive science, with knowledge of distributed cognition theory and experience in cognitive ethnography. Prior to the time of data collection, this researcher had been working on a cognitive ethnographic study of engineering students for two years. During the first half period of the data collection, the researcher visited the APR Lab field site regularly as a participant-observer. The researcher visited the lab every day in the first week and spent two to three hours a day getting to know people and the environment of the lab. The visit consisted of a guided tour to the lab, making introductions to lab members, shadowing daily activities of the lab and a few hands-on experiences of lab work under the supervision. From the second week, the researcher visited once a week at different times and on different days to observe various aspects of daily activities. These daily activities included official meetings, unofficial discussions, trainings, and experiments. In addition to the regular visits, the researcher also attended several pre-scheduled lab activities such as a group meeting, a training session, and a monthly lab meeting. The observation was done usually in the Open Area in the fourth floor and in the Basic lab because the access to the Clean lab and the Chemistry lab was limited for safety reasons. We focused on the interaction among the members, both verbal and non-verbal because we are interested in the ethical decision-making process that comes out of the interaction. Nineteen separate activities of interaction, from a spontaneous discussion among the members to a pre-scheduled research seminar, were observed and recorded. Field notes and photos were taken, and two activities were video-recorded. We performed micro-scale analysis on discourses recorded in field notes, photos, and video and the initial results indicated that we need to change our approach as we explain below.

Initial results

Observation

The researcher regularly visited the APR lab for three months and observed the lab members' daily activities, focusing on interactions among the members in research meetings, lab trainings, and spontaneous group discussions. The researcher attended the monthly meeting and the end of semester meeting where all the lab members gathered and presented their current projects. The researcher also spent time in the Basic lab to observe trainings and experiments. The Basic lab is where many of the machines and equipment for the project are located and where a lot of experiments are conducted. Training for undergraduate students took place in the Basic lab. The researcher also spent much of her time at the Open Area on the upper floor, which post-doctoral researchers and graduate students shared as their 'office' because that is the place in which the most of the conversations occur. The APR Lab had an atmosphere that encouraged discussions among the members. The team members who work for the same project often held unofficial meetings there, and nearby members frequently joined the discussion, providing their opinions even though they did not work on the same project. Undergraduate students who belong to the lab frequently visited this space to ask senior members of the lab questions. From time to time, the professor who leads the lab joined the discussion, and when this type of unofficial meeting occurred, all the people who happened to be present there exchanged ideas and opinions.

For example, one morning, the professor went to get a cup of coffee and on his way, he greeted a lab member and casually asked how his work was going. The student mentioned something interesting that he found and opened his computer file to show it. Soon, people around them stood up or came closer to look at the computer screen. Then, they engaged in a spirited conversation about what they thought the results meant and how the results related to their previous findings. The conversation did not stay on a single topic. Though it started with one student's interests, it moved on to different topics mixed with jokes, anecdotes, and personal stories.

The APR lab holds many official meetings, such as monthly meetings and the end of semester conference; however, students seem to participate more actively in this type of spontaneous discussion. In official meetings, a few members, usually graduate students or post-doctoral researchers, asked questions, and discussions between presenters and audiences were limited. In spontaneous discussions, anyone who happened to be nearby asked questions or shared their opinions freely. Figure 4 shows the two photos of different types of meetings. The left picture was taken at one of spontaneous discussion described here. Lab members surrounded a student who showed his results. One member

Figure 4. A spontaneous discussion (left) and an official monthly meeting (right).

who might have been passing by is now looking over the wall, and we can see that, in the upper right corner of the picture, another member is approaching the group (see arrow). On the right, lab members are watching the presentation at their monthly meeting. If the right-side picture depicts a formal atmosphere of typical research presentations, the left-side picture captures an atmosphere of light chatting, though what is discussed in it is far from light. Overall, numerous free discussions occurred voluntarily and spontaneously almost every day in the lab.

The rare bird problem

The discussion of ethics issues, however, rarely occurred during the observation period. Many of the ongoing projects were related to bioengineering and medical science, but issues such as ethical or social responsibility in their projects were not spontaneously discussed. For example, one of the projects was attempting to develop an electric device that can be connected to a neural system to send and receive signals. The team was working with doctors and surgeons. The issue of interdisciplinary collaboration was frequently discussed, but it was not extended to social responsibility or ethical issues. To develop this device, testing on human subjects is inevitable. The team members were aware of this, but they did not talk about human subject testing. Instead, they talked a lot about how they can convince or teach doctors to understand the background knowledge and function of this new device because they thought doctors' lack of understanding may hamper collaboration. Also, if this new device is completed and commercialized, the price of the device and the cost to patients may bring social issues. Engineers are not free from responsibility for this issue, especially when financial factors such as patent and private funding are involved. The team, however, did not mention this type of social issue. The reason behind this lack of attention toward ethical and social issues is not clear. Perhaps it happens because the engineers do not directly work with actual patients, so they believe that responsibilities are to doctors. Also, perhaps, the team is under the pressure to complete the project; they simply do not have time to think about indirect, long-term social issues.

Another example was observed at a lab presentation. When a team of doctors and engineers presented a project idea of potential gene editing technology, this idea drew a lot of attention that resulted in comments, questions, and follow-up discussions, but attention was mostly focused on technological issues and applications. Ethical responsibilities for or social implications of this idea were not discussed. The gene editing technology can bring a hot debate in multiple perspectives. For example, if this technology becomes available to people, manipulating human genes, not only for a medical purpose but also for personal preference, may happen. Social, cultural, or political preference may intervene and lead to abuse of the technology. Or the idea of gene editing technology itself may be seen as objectionable, an impermissible way of 'playing god.' No such concerns, however, were mentioned among many questions and comments.

Based on the results of the initial ethnographic observation, we found that engineers in this laboratory rarely discussed ethics issues during their everyday activities, and it was difficult to observe voluntary ethics discussions in the engineering lab. *The Rare Bird Problem* arises because, like a rare species of bird that is difficult to observe in nature, engineering ethics discussion or ethical decision-making in engineering activities was difficult to observe in the engineering lab. It was not clear why the lab members rarely discussed ethical issues in spite of an environment that encourages spontaneous discussions. They may be indifferent to engineering ethics, or they may not want to discuss such issues. Nevertheless, we needed to try alternative methods to observe ethics discussions among the lab members.

Revised methodology

The Rare Bird Problem put us in a tricky position. Our background knowledge and theoretical and methodological commitments push us to focus on ethics 'in the wild,' that is, as it naturally arises in the culture and activity situated in the laboratory, to pursue careful qualitative observation and description of the existing culture before engaging in intervention. If an ethics discussion in the engineering lab is a very rare occasion that we cannot see during three months of observation, it could take years of full-time work to get at the phenomenon of interest, and even then, there is no guarantee we would succeed. If an ethics discussion is a very private affair that only happens in an inner circle, it also could take much longer time for the ethnographic researcher to access those trusted circles. Again, there is no guarantee that we would succeed. Considering these impracticalities and risks, we made the decision to revise our methodology so as to explicitly prompt ethical reflection and decision-making, in hopes of overcoming the Rare Bird Problem. This revision necessarily blurs the line between observation and intervention, however.

Mini-STIR interview

The Socio-Technical Integration Research (STIR) protocol (Fisher and Schuurbiers 2013; Flipse, van der Sanden, and Osseweijer 2014; Fisher et al. 2015) is an interventional methodology to broaden research scientists' self-reflection on their research in terms of broad social contexts. STIR uses midstream modulation approach (Fisher, Mahajan, and Mitcham 2006; Fisher and Schuurbiers 2013; Flipse, van der Sanden, and Osseweijer 2014), with an embedded humanist or social scientist using a structured interview protocol to modulate participating research scientists in the midstream of their research processes. Based on the idea of the STIR protocol, we conducted Mini-STIR interviews with the lab members. Our goal in this study using a STIR-based method was not to influence the participants' understanding of ethics but to prompt participants to think about ethics in their research projects. We borrowed the four basic questions of STIR protocol (see Owen et al. 2013) and constructed a structured interview with questions of 'What are you doing?', 'Why do you do it?', 'What other ways could you do it?', and 'Who might be affected?' STIR questions help participants to deepen self-reflection in social contexts. We used STIR-based questions because we hoped that these self-reflection questions would prompt lab members talk about ethics. As a modulation methodology, STIR protocol requires repeated application by an embedded researcher in the lab for an extended period (generally 12 weeks). To prompt and encourage lab members' ethics talk, we used STIR-based questions in a one-time interview and recorded the interviewee's answers. Fifteen members volunteered for the interview, and each interview was done by an individual appointment. We designed this mini-STIR interview to limit the degree of intervention prior to a clearer understanding of the role of ethics in their everyday decision-making.

Ethics toolbox for the engineering lab

To engage the lab members in ethics discussions, we used the Toolbox dialog protocol (O'Rourke and Crowley 2013; O'Rourke et al. 2013). The Toolbox protocol was developed to provide philosophical and practical enhancement to researchers who are engaged in cross-disciplinary research. It consists of a survey instrument and a dialog-based workshop. The survey instruments are organized into various modules in multiple domains; the workshop engages participants in a structured dialog based on the survey results. Toolbox discussions are expected to help research teams create mutual understanding across disciplinary boundaries, and encourage communication and collaboration among the teams (O'Rourke and Crowley 2013; O'Rourke et al. 2013; O'Rourke, Crowley, and Gonnerman 2016). Although our study was not focused on incubating collaboration in cross-disciplinary teams, we hypothesized that the Toolbox discussion would facilitate ethics discussions among the engineering lab members, for two reasons. First, ethical deliberation is not part of the disciplinary expertise of the engineers, and our experience with the Rare Bird Problem showed that it was not a part of their regular interaction in the lab. Second, the lack of naturally-occurring explicit ethics discussion suggests the need to facilitate communication in the way the Toolbox does well.

We modified the Toolbox survey instrument module on 'Values' to speak more specifically to engineering and added two new modules: engineers' responsibility and social implications of engineering. Table 1 shows three core questions and descriptive statements in our modified Toolbox survey. Then we conducted an online survey of the members in the engineering lab. We selected six members who had considerable influence in the lab (see Figure 1) and invited them into the Toolbox ethics discussion. We invited these participants because they were the most active members in the lab, highly connected with other members, and leading many projects. Their opinions could represent influential opinions in the field site lab. One researcher on our research team facilitated the ethics discussion, and another researcher observed and recorded the discussion.

Table 1. Modified ethics toolbox survey questions.

Values	*Core Question: How do values influence engineering design and research?* 1. Value-neutral engineering design is possible. 2. Incorporating one's personal perspective in framing a research question is never valid. 3. When engineers disagree on an issue, they disagree mostly because they do not have all the facts. Such professional opinion has nothing to do with values. 4. Disagreements among engineers can occur when different engineers interpret the facts differently. This happens mostly, because of personal opinions, moral values, personal priorities, or politics. 5. Determining what constitutes acceptable validation of research data is a value issue. 6. The members of this team have similar views concerning the core question.
Engineers' Responsibility	*Core Question: To what extent are engineers responsible for the harm that might result from their designs and products?* 1. Engineers are NOT responsible because it's the people who use the product, who are responsible. Engineers may be concerned, but they have no control over how others use their design and product. 2. Engineers are NOT responsible because they cannot possibly know all the long-term effects of their design and products. 3. Engineers are NOT responsible because once a design is done and a product is made, others such as legal system, government, company, and professional community should check its effects. The engineer's job is only to make them. Engineering and moral questions are separate. 4. The responsibility should be shared about equally between the engineers and society. 5. Engineers should be held responsible because, if their design and product can be used for both good and bad purposes, the engineers must promote the good use and stop the bad use. 6. The members of this team have similar views concerning the core question.
Social Implication of Design Products	*Core Question: To what extent are engineers concerned with the potential effects that might result from their designs and products?* 1. Engineers are most concerned with the possible *harmful effects* of their design and product, so they carefully test their design in order to prevent harmful effects from occurring. 2. Engineers only look for *beneficial effects* when they design things or when they apply their design to make the products. 3. Engineers always have to make trade-offs (compromises) between the positive and negative effects of their design products. 4. Engineers are concerned with how their design products may help in resolving social problems such as poverty, unemployment, pollution, and overpopulation. 5. It depends upon the field of engineering. For instance, in biotechnology, engineers are highly concerned with the potential effects, however, in military research, engineers are least concerned. 6. The members of this team have similar views concerning the core question.

Data collection and analysis

During the second half of the period, we devised and implemented methods to flush out rare-bird-like ethics discussions. Fifteen Mini-STIR interviews were conducted, ranging from the post-doctoral researcher to the undergraduate assistant, and interview sheets were collected and analyzed. The modified Toolbox discussion with six invited participants was conducted and video-recorded. Figure 5 shows the process of data collection and analysis over the full course of the study.

Final results

Mini-STIR interview

During the second half of the observation period, we tried to prompt ethical reflection and facilitate ethics discussion. All 15 interviewees answered the question 'What are you

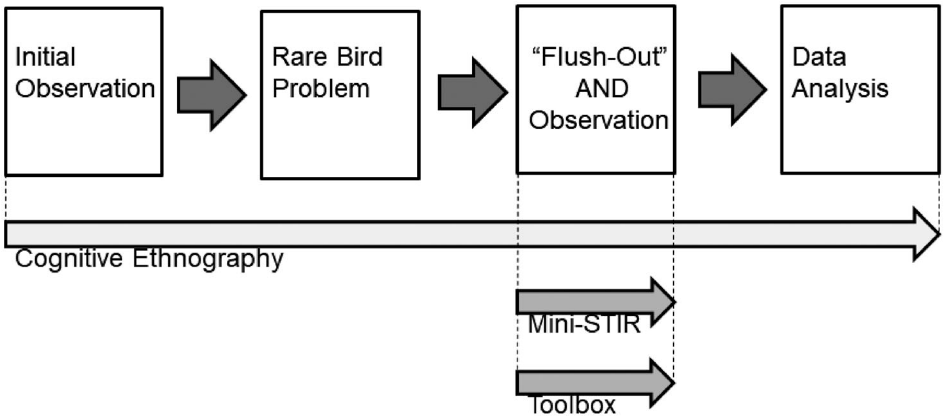

Figure 5. The process of data collection and analysis.

doing?' with a detailed explanation about their projects or current activity. In response to the 'Why do you do it?' question, six members mentioned personal interests such as 'I have been always fascinated with this topic,' 'For understanding and knowledge,' 'Because it is interesting,' 'It chose me,' and 'for intellectual stimulation.' Four members mentioned professional interests such as 'To fabricate this kind of material,' 'To test if it works in micro scale,' 'To create technology that impacts the world,' and 'Design exploration.' Four members answered with practical reasons such as 'cost-effective' 'familiar work,' 'to have experience in research,' and 'because I joined a new project.' Most of the interviewees did not answer the question 'What other way could you do it?' or answered that there is no other way to do it or it is difficult to do it in any other way. Two members said that a very creative idea or a new idea will be needed to find an alternative way. For the question 'Who might be affected?' the lab members mentioned academic disciplinary areas, researchers, funding organizations, companies, consumers, future research, patents and copyrights. Table 2 shows a summary of interviewee's responses to questions.

None of the engineers mentioned ethical considerations (such as harms or impact on rights) or broad social impacts. One of them said that they never thought about the social implications of professional ethics. Interestingly, only one member initially mentioned that the project will help people (interviewee # 9), but when prompted for ethics direction, most of the interviewees mentioned that their projects will eventually help people. Only one interviewee (#11) brought up ideas related to ethics on his own. When asked 'What other way could you do it?' he answered that it may be possible to find a way of cultivating a more ethical culture, unlike the current culture in which managers sometimes make unethical decisions, or decisions with unethical consequences, which puts engineers in an 'uncomfortable situation,' an ethical dilemma. In a more ethical culture, 'various lines of work and research can be out of uncomfortable situation [*sic*],' i.e. engineers will not have to face such dilemmas or will have the autonomy or resources to make ethical decisions. This interviewee was also the only one who mentioned social responsibility for indirect outcomes. Although he belonged to the lab, he was not an engineer, but rather a business associate who was helping to establish a company based on a patented

Table 2. Summary of responses from 15 interviewees to the Mini-STIR questions (responses to 'What are you doing' are not included because they are technical descriptions of projects).

	Why do you do it?	Who might be affected?	What other way could you do it?
1	For understanding & knowledge	Academia, students, further funding, more collaborators	There is no other way
2	It chose me	Entire culture, environment (in research area)	No answer
3	It chose me	Industrial, future research	No answer
4	Practical reason (cost-effective)	Consumers, companies, patent/copyright 'Not concerning for social implication of professional ethics, never thought about it'	No answer
5	I've always been fascinated with this	Healthcare users, patients, doctors	Selling the idea might be useful (or not)
6	Intellectual stimulating	Funded organization, Responsibility shared by engineers and funding organization Eventually social impact	No answer
7	Familiar work	Medical areas	Environmental or biological
8	To create technology that impacts the world	Medicine, companies, lay people Psychologically beneficial to people	(Not many) because of ethical limitation in implanting device in the body
9	To fabricate or develop materials	It will help people	Getting helping hands from undergraduates and discussing it with them
10	Design exploration	Secondary professionals be influenced	Different way is not really possible
11	Because it is interesting	Professional companies, secondary customers Social responsibility for indirect outcomes	Making a culture with higher ethics 'various lines of works/research can be out of uncomfortable situation'
12	To test if it works in micro-scale	Researchers for now If industrialized, every day customers too.	New idea needed
13	Helping research	Students/researchers	Learning by working
14	To have experience in research	Team members	No answer
15	Because I Joined a new project	No clear cut in there	Creativity needed

idea. Therefore, the question remains whether his thinking is different from other members because he has a different background outside of engineering.

Toolbox discussion

To facilitate ethics discussions, we organized a Toolbox discussion for the engineering lab members. Based on the Toolbox protocol, we prepared a survey instrument and conducted an online survey of the APR Lab members. We modified a Toolbox survey by adding two engineering ethics sections to the Toolbox values module. Our survey consisted of three sections. In each section, there was a core question, and six statements related to the core question. Participants answered each statement on a Likert scale from 1 (Disagree) to 5 (Agree). In every section, the last statement was 'The members of this team have similar views concerning the core question.' The first section was about values in science and engineering, the second section was about engineers' responsibility, and the third section was about the social implications of engineering design products.

After conducting the online survey, we invited six lab members to the facilitated discussion. APRL has approximately 70 members, so it is impossible to invite all of them to the discussion. Instead, we selected six members who played essential roles in the lab. Each of these participants worked as team leaders, conducted many research projects, and half of them had industrial experience. Among the participants, four of them were PhD students, one member was a research professor, and one member was a senior engineer. The facilitator did not actively participate in the discussion, but only prompted the discussion based on the survey result. For example, the facilitator prompted, 'Most of your lab members agreed with this statement. How about you?' or 'Your lab members had a lot of different opinions for this statement. What are your opinions?' The facilitator encouraged every participant to voice their opinion and led the discussion to cover all the interesting survey results; however, he did not offer his opinion nor guide the discussion in a particular direction. We observed and video-recorded the discussion. Through this observation, we noticed that participants demonstrated a narrow and rigid understanding of engineering ethics in terms of social responsibility. For example, participants agreed that engineers cannot take responsibility or be held responsible because, often, they do not receive enough information to make the final decision. In the following example, two participants talk about why they think that engineers are not responsible for the consequences of an engineering project:

> A: People who are actively working on a design are doing so to meet a specific set of metrics, right? and in that little primer space that they're given, I don't think they should be held responsible. I mean they should not necessarily make it with: You know what would be cool? If we [unclear] … explode! … [unclear]
>
> B: [interrupting]: They-They're not being told. They're not being told. They are only given that little – little amount of information that THEY NEED to perform their own work. They are not seeing usually the full – full picture at all.
>
> A: I agree.

Based on this type of argument, they shifted the ethical responsibility to managers or someone in the higher position in the hierarchy because they are the ones who make the final decision. Shifting ethical responsibility to others and keeping engineers' responsibility within technical domain have been observed undergraduate student teams, too. In our previous studies, we observed and discussed shifting ethical responsibility in engineering work in detail (Lee et al. 2015, 2017). They also mentioned that when engineers work for the company, their work constitutes implicit approval for the aims of the company, so it is individual engineer's choice to work or not to work for the company that may be the only crucial decision in terms of ethical responsibilities. Overall, however, participants were willing to discuss engineering ethics, and during the hour-long discussion, participants actively discussed diverse issues including value related or value neutral idea in engineering, the relationship between information hierarchy and engineers' responsibility, and social implications of engineering.

Discussion

We expected to study engineers' understanding of engineering ethics as situated and distributed cognition by observing engineers' ethics discussions in their work environment. Engineers' ethical decision-making during engineering practice is necessarily a complicated cognitive process, and we expected to capture and analyze such a process through observation of ethics discussions in the engineering lab and through analysis of those discussions based on cognitive ethnography. However, our initial observation in the engineering lab indicated that it is not easy to observe engineers' discussions of ethics or ethical decision-making in their everyday activities. Engineers in our field site rarely discussed ethics, although they discussed many other shared problems actively and voluntarily.

This finding, which we named the 'Rare Bird Problem,' raised two questions for our research plan. The first question was how we could observe engineers' ethics discussion or ethical decision-making in the engineering lab. The second question was why engineers rarely discussed ethics in the engineering lab. To address the first question, we tried two methods to flush out engineers' ethical reflection. These methods both presented potential challenges for us, insofar as we started from the point of view of needing to observe and understand ethics in practice before engaging in any direct intervention. One method that we applied was a Mini-STIR interview modified from the STIR protocol of Fisher, Mahajan, and Mitcham (2006); Fisher and Schuurbiers (2013); Fisher et al. (2015). While the STIR protocol aims for midstream modulation that encourages participants to reflect and change, our Mini-STIR interview prompted interviewees to make potential ethical considerations in their work explicit. In this respect, we tried to maintain the ethnographic 'middle distance,' neither the full participant-intervention called for in the STIR protocol, nor a passive observer position.

The second method we applied to deal with the Rare Bird Problem was a facilitated ethics discussion modified from the Toolbox protocol. If Mini-STIR was a conversation between the researcher and the engineering lab member, Toolbox discussion was a conversation among the lab members facilitated by a survey instrument and a discussion facilitator. The Toolbox protocol was designed to encourage mutual understanding among cross-disciplinary team members (O'Rourke and Crowley 2013; O'Rourke et al. 2013). We borrowed and adapted the Toolbox format to encourage the engineering lab members to talk about ethical considerations in the engineering lab. The facilitator was not a full participant in the discussion (e.g. they did not give their opinion) and only let the participants discuss prompted topics based on the pre-survey. Unlike the Toolbox survey instrument, our survey focused entirely on questions related to ethics and values in engineering.

From the observation of the facilitated ethics discussion, we obtained a clue about our second question – why engineers rarely deliberated explicitly about ethical issues in the engineering lab. Participants were willing to discuss prompted ethics issues, and they actively participated in the discussion. They were not indifferent to ethics issues, and they did not show reluctance to discuss ethics. In our interpretation, the discussion indicated that the members in the engineering lab did not see the discussion of ethics as relevant to their everyday activities. They do not readily identify or act on occasions for ethical deliberation, though in some sense they had plenty of opportunity to do so. Once an opportunity was *explicitly* given, they discussed ethics issues as seriously and intensely as they had previously been observed discussing technical engineering problems. The source of the problem is that the engineers do not recognize opportunities to discuss ethics in the engineering lab in spite of the environment that encourages free discussions. This may be a result of training that does not include regular, explicit ethical deliberation on the occasions that it is relevant to their everyday activities.

Cech (2014) shows that the current culture of engineering causes its members to disengage from ethical or social issues as they become further enculturated into it. This culture of disengagement may mislead engineers to think that explicitly discussing ethics is not one of the important engineering habits of mind.[2] Even though engineers believe that engineering ethics is important, regular ethical reflection and discussion are not what engineers are enculturated to do as part of their everyday research activities, and thus do not become habits of mind. In the context of U.S. education standards, the National Academy of Engineering (NAE) promotes ‘attention to ethical considerations’ as one of six essential habits of mind (Loveland and Dunn 2014; NRC 2010). It seems, however, that this is not realized in engineering practice. Through higher education and engineering practice, engineers appear not to have cultivated attention to ethical considerations as part of the engineering habits of mind.

This phenomenon may have resulted in engineers’ narrow and rigid understanding of engineering ethics. Though our research subjects showed enthusiasm for the importance of ethics to engineering and willingly discussed ethical issues when prompted, they seemed to see the scope of engineering ethics as rather limited. In our results of Mini-STIR interview and of the facilitated ethics discussion, the engineering lab members showed a narrow view of the social responsibility of engineering. They shifted social responsibility of engineering to others such as managers and frequently made the excuse that engineers do not have enough information about the entire situation to make final decisions with broad social impacts. In a study of STEM students’ views on social and civic responsibility, Garibay (2015) reported that STEM students developed negative relationship to social and civic responsibility through college education. Students in STEM disciplines came to think that working for social change is inconsequential to achieving career goals, compared to non-STEM students. Considering that the lab members are either highly educated professional engineers or engineering students, they also have been developing the negative relationship to social responsibility through their education and experience.

The lab members also mentioned engineers’ implicit approval. In their view, engineers that work for a particular company implicitly approves of the projects of that company that the engineers contribute to. Thus, the lab members understand engineering ethics to involve the individual engineer’s moral responsibility for those projects, broadly construed. Basart and Serra (2013) pointed out that engineers’ ethics are only part of engineering ethics, and the heroic engineer who is morally strong enough to solve any ethical problem is not a realistic model of ethical engineers. Engineers work within the complex system and social responsibility of engineering needs to take into account the complexity of the engineering system, rather than focusing exclusively on individual engineers’ ethics. The lab members, however, appeared to think that engineering ethics is the same as engineers’ ethics.

Our previous study of ethical understanding in undergraduate student teams working on engineering design projects found that there were complicated, multi-layered understandings of ethics among engineering students (Lee et al. 2015, 2017), but in this study, we did not obtain evidence of such complicated understandings. Although we tried to flush out the members’ ethical considerations, the result was only modestly successful because we only found that the members had a narrow, one-dimensional understanding of ethics. We posit that methodological limitations may have resulted in limited findings. Nevertheless, we can make suggestions to address two questions we had in this study. First, to study the situated understanding of engineering ethics, an innovative method beyond a cognitive ethnographic approach is required to draw out engineers’ attention to ethical considerations in daily practice. Potentially an action-research methodology would be beneficial, as the attempt to separate observation from intervention seems unworkable. Second, to promote ethics discussion in daily engineering practice, engineers need to change their minds to accept that attention to ethical considerations is actually one of the engineering habits of mind.

Conclusion

We initially designed a study of engineering ethics through a situated approach. Cognitive ethnography was our core methodology for observing and analyzing the engineers' ethics discussions in the engineering lab, as this is a proven methodology for understanding situated cognitive practices in their natural setting. Early in the process, we faced a problem that engineers rarely discussed ethics in their engineering practice: *the Rare Bird Problem*. It turns out that cognitive ethnography fails as a methodology for studying the phenomenon of interest. We pursued two methodological innovations to a standard cognitive-ethnographic approach in order to overcome this problem.

Although our effort to flush out and attract ethics discussions in the engineering lab brought modest success, we conclude that there is a need for an innovative method to study situated and distributed engineering ethics, because engineers' ethical reflection, discussions, and decision-making are hard to observe in natural environment of engineering practice. We also concluded that engineers may not consider discussing ethics as a necessary engineering habit of mind. The disengaging culture of engineering ethics that makes engineering students avoid, disregard, or indifferent to ethics through higher education has been a puzzling issue in engineering education (Cech 2014; Culver et al. 2013; Garibay 2015), despite the fact that engineering education research and standards have been emphasizing socially responsible engineering ethics (Basart and Serra 2013; Harris 2008; Volkwein et al. 2004; Zandvoort et al. 2013). These findings corroborate our concern that the Rare Bird Problem as well as the limitations of our intervention in part reflects a troubling feature of engineering culture.

Engineers recognize the importance of ethics in engineering, but they did not seem to incorporate ethical reflection and discussion or explicit ethical decision-making into their daily practice. This may be due to training that fails to incorporate attention to ethical considerations into engineering habits of mind. Engineering education and engineering practice may need to focus on the relationship between engineering ethics and engineering habits of mind, and work on how to make thinking, talking, or acting about ethics as engineers' habits in daily engineering practice.

Notes

1. The name of the lab has been altered to protect the identity of the participants.
2. As Katehi, Pearson, and Feder (2009) remind us, "The term 'habits of mind,' as used by the American Association for the Advancement of Science in *Science for All Americans* (1990), refers to the values, attitudes, and thinking skills associated with engineering."

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