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ORIGINAL RESEARCH/SCHOLARSHIP

Guiding Engineering Student Teams' Ethics Discussions with Peer Advising

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Abstract

This study explores how peer advising affects student project teams' discussions of engineering ethics. Peer ethics advisors from non-engineering disciplines are expected to provide diverse perspectives and to help engineering student teams engage and sustain ethics discussions. To investigate how peer advising helps engineering student teams' ethics discussions, three student teams in different peer advising conditions were closely observed: without any advisor, with a single volunteer advisor, and with an advising team working on the ethics advising project. Microscale discourse analysis based on cognitive ethnography was conducted to find each team's cultural model of understanding of engineering ethics. Cultural-historical activity theory (CHAT) analysis was also conducted to see what influenced each team's cultural model. In cultural model, the engineering team with an ethics advising team showed broader understanding in social implications of engineering. The results of CHAT analysis indicated that differences in rules, community, and division of labor among three teams influenced the teams' cultural models. The CHAT analysis also indicated that the peer advisors working on the ethics advising project and the engineering team working on engineering design project created a collaborative environment. The findings indicated that collaborative environment supported peer ethics advising to facilitate team discussions of engineering ethics.

Keywords Engineering ethics · Peer advising · Cognitive ethnography · Cultural-historical activity theory (CHAT)

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Introduction

The focus of current thinking about engineering ethics education is no longer on preventing disasters or upholding a code of conduct. Instead, the focus has been shifted to ensuring broad social responsibility of engineering (Fuentes et al. 2016; National Academy of Engineering 2005; Zandvoort et al. 2013). Studies of engineering students' understanding of ethics, however, show that engineering students still understand the social responsibility of engineering in a narrow and rigid way (Cech 2014; Culver et al. 2013; Garibay 2015; Lee et al. 2015). Moreover, students' understanding of ethics and social responsibility tended to *decrease* through higher education (Cech 2014; Garibay 2015). For example, Cech (2014) found that students' concern for public welfare declined through the typical four years of engineering education, and Garibay (2015) found that STEM students' views on the importance of working for social change had diminished at the end of college education. There seems to be a discrepancy between what engineering ethics education emphasizes and what engineering students actually learn through higher education.

This study is a part of a larger research project that studied engineering ethics as a socially situated activity shaped by how undergraduate and graduate students understand engineering ethics and make decisions in practical situations. Undergraduate students' understanding of engineering ethics was investigated by observing student project teams and classifying their understanding of engineering ethics and social responsibility of engineers. The research project also includes a pedagogical intervention using peer advising. This study focuses on how peer advising affects undergraduate project teams' understanding of engineering ethics, and looks at the phenomenon with a high level of qualitative detail. The main research question of the study is "When and how can peer advising help an engineering student team engage and sustain its engineering ethics discussion?" followed by supporting questions such as "What are mental models of helpful peer advising processes?" and "What are conditions or environments that support peer advising?"

To explore these research questions, this study observed how engineering student teams discussed ethics pertaining to their engineering design projects. Best practices in engineering education should include team-based projects because professional engineering practices rely heavily on teamwork. Teamwork is more than just a task accomplished by individual contribution of team members. Teamwork is a complex process of collective cognitive, behavioral, and attitudinal activity (Salas and Fiore 2004). Discussing ethics issues pertaining to the team project is an activity based on team cognition. Considering ethics issues, understanding and decision-making of the engineering team are not the same as understanding or decision-making of an individual engineer in the team (Basart and Serra 2013). Therefore, a student project team, not an individual student, was a unit of analysis.

Engineering emphasizes the importance of including relevant expertise and of multidisciplinary collaboration (Volkwein et al. 2004). The approach to peer advising on ethics in this study is based on the concept of cross-disciplinary collaboration, in which different experts in different areas collaborate to solve a shared problem. Students from the Philosophy of Science and Technology course joined engineering student teams' discussions in the role of peer ethics advisors. The expectation was that two different groups of students—one from engineering and the other from humanities—could collaborate to discuss engineering ethics issues by effectively making use of their multidisciplinary perspectives.

The next section briefly explains situated learning, distributed cognition, and cultural-historical activity theory (CHAT) as theoretical frameworks. The third section explains the methods and study design. This study takes a team discussion as a cognitive activity and investigates its process using micro-scale analysis. Thus, cognitive ethnography, which aims to analyze the cognitive process in detail, and CHAT analysis, which aims to analyze the relationship between cognition and activity, are the main methodologies in this study. Data analysis using cognitive ethnography and CHAT is explained in the third section. The fourth section presents results in the form of the cultural model and of the CHAT diagram respectively. These cultural models and CHAT diagrams are discussed in the fifth section to explain the differences among teams and the influence of peer ethics advising. The conclusion and the implication for engineering education are presented in the last section.

Theoretical Framework

This study is based on two theoretical frames, one is situated learning and the other is distributed cognition. Learning is situational, shaped by a culture of practice (Lave and Wenger 1991). Team-based projects in engineering education enhance students' learning because conducting a team project becomes a learning experience similar to real-world practice (Volkwein et al. 2004). Students' reasoning and decision-making in engineering practice, including engineering ethics, are affected by situational factors including social norms and culture (Fuentes et al. 2016). Discussing ethics issues of the engineering design project is a situated learning activity; therefore, this study is designed to observe these activities to investigate students' understanding of engineering ethics.

Hutchins (1995) explained that while conducting cognitive activities, cognition can be distributed across systems that include brains, bodies, artifacts, environments, and social interactions. According to Hutchins' theory of distributed cognition, when a student team discusses ethics issues of their engineering project, their cognition and decision-making about those issues is distributed across team members, the contexts of the projects, the tools and resources that the team uses, environmental conditions, and social interaction among the team. The discussion is part of the cognitive problem-solving process, and not merely an input to it. In a typical experimental study design, these elements may be considered as confounding variables that influence the result. Instead, this study treats a student team's ethics discussion as a distributed cognitive activity, and this study is designed to observe each team's discussions as a unique case in which cognition is distributed. In addition to situated learning and distributed cognition, CHAT became an important theoretical framework to make the relevant methodological design.

Situated Cognition and Situated Learning

Situated cognition theory views cognition as the dynamic interaction between agents and environments, rather than as the outcome of function or process within the agent's mind. (Lave and Wenger 1991; Roth and Jornet 2013). According to Lave (1988), the interaction in which situated cognition emerges occurs at multiple levels, and each of these levels needs to be a mode of analysis to understand situated cognition. First, there is an interaction between semiotic systems and social structures, and Lave (1988) calls this level of analysis "constitutive order" (p. 177). Second, there is an interaction between agents, setting, and activity, the level of an "experienced, lived-in world" (p. 179). Finally, *practices* consist of an interaction between experienced, lived-in world and its constitutive order. Lave argues that cognition must be analyzed, not at the level of abstract cognitive process alone, but in terms of a theory of practice involving the relation or interaction between the experienced, lived-in world and its constitutive order. Based on the situated cognition theory, Roth and Jornet (2013) establish the following set of hypotheses that explain how cognition appears in an everyday situation: (1) *Cognition is embodied*—cognition arises when there is a physical interaction between agents and environments. (2) *Cognition is fundamentally social, distributed, or enacted*—Cognition is related to its social context because cognition arises when an agent is interacting with other agents or with her social environment. During the social interaction, cognition is often socially distributed across the settings. Sometimes cognition is enacted to fulfil the purpose of agents. (3) *Cognition often works without representations*—Cognition arises even when an agent does not have explicit concepts or ideas in mind. An agent still can engage in cognitive activity by interacting with the environment.

Learning, one of the most complex cognitive activities, is also situational and consists of two components: agents and contexts (Young 1993). Situated learning is an activity in which agents interact with social, cultural and physical contexts to construct knowledge, and learned knowledge is considered as the outcome of the relationship between agents and contexts (Billet 1996; Young 1993). Wilson (1993) suggests that learning is mostly a social activity, and learning ability is often structured by situationally provided tools. In situated learning, learners form a community of practice in which learning occurs (Lave and Wenger 1991). In college engineering education, students are required to conduct team-based projects to design and produce engineering products. This type of team-based project is highly recommended because it models real-life situations in the engineering world (Volkwein et al. 2004). It also provides a good opportunity for situated learning. As Wilson (1993) points out, engineering students' learning through team projects is a social activity, and their learning ability is structured by situationally provided tools during the team projects. In this case, a student team becomes a natural community of practice. Situated learning also conceptualizes expertise in a situational perspective (Billet 1996). In situated learning, a newcomer to the community of practice becomes an expert through peripheral learning, gradually working from simple tasks to the professional task (Lave and Wenger 1991). An *expert* is a person who has high capability achieved through practice. Engineering ethics requires expertise from two domains: engineering and ethics. Learning engineering ethics needs to take place in a community of practice through the social activity of participation (Case and Jawitz 2004). In the perspective of situated learning, discussing ethics issues of the engineering team project is an ideal opportunity to learn engineering ethics in practice.

Distributed Cognition

Distributed cognition is a theory of human cognition that emphasizes the spread of cognitive processes across systems with flexible elements including brains, bodies, artifacts, environments, and social interactions (Hutchins 1995; Sutton 2006). Frequently mentioned examples of distributed cognition include a team of naval navigators' work to calculate the ship's location using instruments and protocols, airline pilots' flight using instruments in the cockpit, and human interaction with computers (Heersmink 2017; Hutchins 1995; Hutchins and Palen 1997). There are different views on how cognition is distributed; on one hand, cognition in general is considered distributed, and on the other hand, individual cognition and distributed cognition are distinguished and considered to be dynamically interacted (Salomon 1993). Hutchins (2014) argues that distributed cognition is a perspective through which cognition can be viewed, rather than a distinctive *type* of cognition. According to Hutchins (2014), cognition emerges when elements of a cognitive system interact with one another, and all cognitive processes include distributed processes at various scales. Therefore, any cognitive process can be studied from the distributed cognition perspective, and the boundary of the unit of analysis is determined by the scale of the cognitive process and by the scale of the cognitive system carrying out that process. Decision-making by a team is considered to be a cognitive process that is distributed across the cognitive system of humans and technological artifacts, similarly to the example of the naval navigating team's determination of the ship's location (Hutchins 1995).

By contrast, ethical decision-making may not be as easily analyzed from the perspective of distributed cognition, because it is not clear whether morality and responsibility, involved in ethical decision-making, are also distributed. Floridi (2013) suggested that morality can be distributed across the cognitive system. He argues that morally relevant actions can be seen as an accumulated result of smaller actions, where each small action is morally neutral or morally negligible. In his view, the cognitive system is a multi-agent system that consists of small systems that produce small actions. Thus, the morality of the multi-agent system can be distributed across the small systems. Verbeek (2011) also suggests that morality can be distributed across the system that consists of humans and technology. Verbeek (2011) considers moral agency to be distributed across the hybrid system of human and nonhuman entities, and because technology is closely embedded in human decision, neither humans nor technology influences moral decision exclusively. Heersmink (2017) also suggests that responsibility can be distributed across the cognitive system that consists of humans and technological artifacts, but artifacts cannot take responsibility

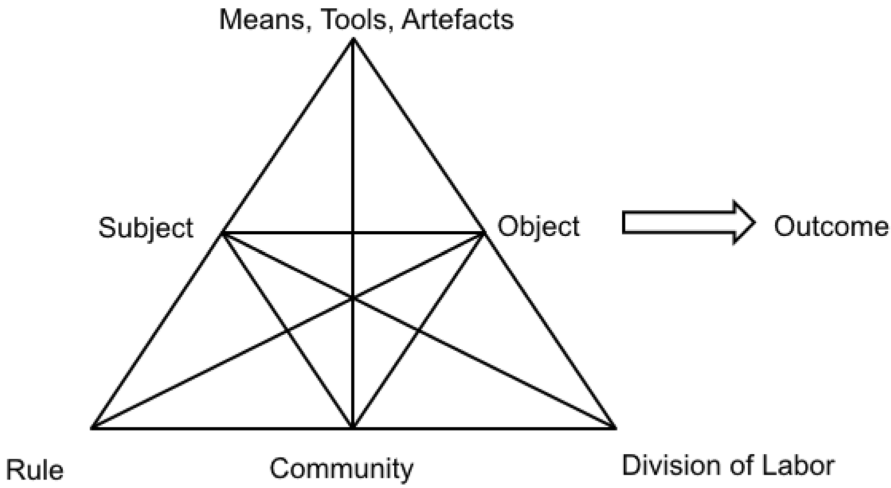

Fig. 1 The CHAT mediational triangle. See Engeström (1999)

alone. Sometimes, responsibility is distributed within the social system. In this case, different human elements, such as social groups, can share distributed responsibility. In engineering, for example, ethical responsibility can be distributed across engineers and users. If we can consider that morality and responsibility can be distributed, we can conclude that ethical decision-making is also a distributed cognitive process.

Cultural-Historical Activity Theory (CHAT)

CHAT is a theoretical framework that aims to understand the relationship between the human mind and human activity through a cultural-historical approach (Cole 1996; Engeström 1999). A cultural-historical approach considers cultural, historical, social, and environmental elements as parts of the human activity system. In many cases of distributed cognition, how cognition is distributed depends on what kind of activity it is along with different forms of mediation, division of labor, and social rules (Cole and Engeström 1993). CHAT analysis is well suited to capture the relationship between interconnected elements within an activity system (Roth and Lee 2007). The model of an activity system in CHAT is often represented by a triangular diagram called a "mediational triangle," composed of seven elements: subjects, objects, mediating artifacts, rules, community, division of labor, and outcomes (Engeström 1999; Patchen and Smithenry 2014; see Fig. 1). These seven elements are important elements compose the activity system, and relationships among these elements constitute the characteristics and processes of an activity. CHAT analysis to study an activity is conducted by mapping observed behaviors, artifacts, and features of the environment to mediational triangle and examining the relationship among seven elements. In this mediational triangle, the upper part of the triangle shows the basic subject-mediator-object relationship in action, while the bottom part shows how this action is further mediated by components of the social context such as social rules, members of community, and division of labor (Cole 1996).

Methods

General Project Design

This section describes the general research design of the engineering ethics education research project to which this study belongs. Engineering student teams working on engineering design projects were recruited and asked to discuss ethics issues related to their design projects. Senior Design Project (SDP) is a required course for senior engineering students in the program that constituted our field site. This course requires students to complete a team-based project over a period of two semesters. Student teams are also required to address the ethical aspects of their design projects on a publicly displayed poster and in their final reports. To help students explicitly address these ethical aspects of their design projects, multiple ethics discussions were assigned in the SDP course. The course instructor was a member of our research team and supervised the implementation of ethics discussion activities. Four SDP teams were recruited in the first-year pilot study and sixteen SDP teams were recruited in the second-year full term study. The study was conducted under Institutional Review Board approval. The students conducted ethics discussions as course activities, while the participation in the study was voluntary. If students did not give informed consent or withdrew their consent, the data about that team was removed from the study.

Teams were randomly assigned to two conditions. In the control condition (CC), teams discussed ethical considerations of their project on their own using a general prompt, while teams in the intervention condition (IC) were joined by peer ethics advisors. Peer ethics advisors were students who were taking a philosophy of science and technology course. These peer ethics advisors were expected to provide diverse perspectives that could enrich engineering ethics discussions. In the first-year pilot study, the SDP teams were asked to discuss ethics twice during the second semester of their projects. Among the four participating teams, two teams were assigned to the control condition and discussed ethics issues without peer ethics advisors. The other two teams were assigned to the intervention condition. They discussed ethics issues on their own first, and a peer ethics advisor joined them at the second discussion. All four participating teams in the first-year pilot study were observed and video-recorded. In the second year, sixteen participating teams were assigned to two conditions. Three teams in each condition were randomly selected to observe and video-record.

Ethics Advising Design

After the pilot study in the first year, some SDP teams demonstrated defensive or uncomfortable attitudes toward the ethics advisor during the discussion. Often, the discussion turned out to be a question and answer session, in which ethics advisors asked questions and SDP teams answered them, and the exchanges of ethical views between the two parties were infrequent. Sometimes ethics advisors' questions were received by SDP teams as irrelevant for their design project, which made SDP teams respond that those questions had "nothing to do with our project" or that they had

Table 1 Ethics advising environment in the first and the second year

	Year 1 (Pilot)	Year 2
Role of ethics advisors	Consultant	Partner
Nature of discussion	Intervention to improve SDP teams' ethics understanding	Collaboration to enhance ethics aspects in SDP teams' design projects
Discussion participants	Single advisor in each SDP team	Ethics advising team & SDP team
Ethics advisor's contribution	Joined at the later stage of the project	Joined at the beginning stage of the project
	Participated in one of two discussions	Participated in all discussions
Training for how to advise	No particular training	Instructions in the class

"never thought about it." In one case the response from the SDP was actively hostile to the advisor's questions. There are a few possible reasons for this uncomfortable situation. First, ethics advisors joined in the second semester of the SDP projects, when SDP teams were in their final stage of their design project. Apparently, it was not a good time for SDP teams to think about possible ethics issues related to their project. Second, both SDP teams and ethics advisors were provided with little explicit guidance about the ethics discussion and the role of ethics advisors, as we initially wished to see the interaction unfold organically. This may have created the misunderstanding that the ethics advisor came to teach ethics to the SDP team or to make ethical judgments about their project, and in turn this may have triggered defensive or uncomfortable attitudes from SDP teams.

In response to these problems, the protocol of ethics advising was changed in the second year. First, ethics advisors joined the discussion from the beginning of the SDP course, so SDP teams could discuss ethics aspects of their design project with ethics advisors as early as the planning stage of their projects. Second, the role of ethics advisors *as advisors* and the open nature of the ethics discussion were made clear to both ethics advisors and SDP teams. Third, instead of a single ethics advisor, ethics advising teams were formed and assigned to SDP teams to participate in the discussion. These peer ethics advisors were students enrolled in a philosophy of science and technology course, and one of the course requirements is a team project of professional ethics advising. Therefore, these ethics advising teams were also conducting a course project by helping SDP teams in their ethics discussion. Ethics discussions became a collaborative activity between SDP teams and ethics advising teams. To encourage a collaborative environment, the role of the ethics advising team was defined as a partner in discussions that seeks to identify, investigate, and resolve ethical concerns of engineering design. Ethics advising teams' role was neither correcting the SDP team's errors nor teaching ethics to the team. In addition to the knowledge about current studies of engineering ethics, ethics advising teams received instruction in the philosophy of science and technology course about the nature of SDP projects and the protocol to engage SDP team in discussion. Table 1 summarizes the changes made in the second year to create friendly and collaborative environment for SDP teams and peer ethics advisors.

Participants' and Course Background

All engineering and computer science senior students at our field site are required to complete team-based capstone project or Senior Design Project (SDP). Each department has slightly different course requirements and a project management plan. The students who participated in this study are from the Department of Electrical and Computer Engineering. Students form a project team, choose a design topic, and select a technical advisor from the faculty. Some projects are sponsored by a company or faculty member, in which case they will also deal with a hiring customer. Each team usually has between four and six members,

During the Senior Design I and Senior Design II courses, students develop their projects for two consecutive semesters. Students earn three credits each semester. In Senior Design I, the entire class meets weekly with an instructor in addition to team meetings with their technical advisor and customers (if any) and individual research and development tasks. In Senior Design II, the entire class usually meets only twice during the semester, at the kick-off meeting in the beginning of semester and at the check-off meeting in the middle of semester. This schedule frees students to concentrate on their projects.

The course instructor(s) coordinates the SDP processes, teaches best practices and procedures for project management, and helps students in constructing teams and proposals. The technical advisor helps conduct a project. The course requires each SDP team to submit a project proposal, hold weekly team meetings, meet performance metrics, submit weekly progress update reports, give a short oral presentation at the end of each semester, make a poster presentation at the end of each semester, and submit a final report and project results. These requirements are also the grading criteria. Invited judges score the presentations and posters, and these scores determine the grade on these assignments. Ethics is emphasized as a core component of the project and required to be explicitly addressed in the poster and the final report. SDP students took a required ethics course in their junior or senior year, but experience and knowledge of ethics beyond this required course are determined by each student's interests and circumstance.

Students who participated as peer ethics advisors were enrolled in one of three philosophy of science and technology courses. These courses include "Science, Technology and Values," "Philosophy of Technology" and "Gender, Science, and Technology." All courses included content related to professional ethics in science and technology, such as "ethics of data gathering," "ethics and politics of design," and "feminist bioethics." Students read and discussed each topic, took a final exam and wrote an individual research report. Most students who enrolled in these courses were majoring in Arts & Humanities or Arts and Technology, but some students were STEM majors. As described in the Ethics Advising Design section of this paper, a practical ethics advising group project was added to the course in the second year. Its purpose was to advise engineering students on the ethics issues in their senior design projects. Each ethics advising group consisted of three to four members. The core goal of peer ethics advising was to provide benefits for both engineering students to obtain different perspectives on ethics issues of their projects and for ethics advisors to experience practical advising of ethics. Before meeting engineering teams, these peer ethics advisors learned about the nature of senior design projects, information about this research, and informed consents along with voluntary participation in the research. They also studied the National Society of Professional Engineers (NSPE) Code of Ethics. The instruction sheet containing the collaborative approach protocol was provided to peer ethics advisors. The instruction included the expected role of ethics advisors and the guideline for how to proceed. For example, the ethics advisors' job is described as "not to tell them what to do, to police them, or to tell them what is right or wrong; rather, it is to help facilitate a better understanding, first, of their own ethical agency and responsibilities in the course of the project, second, to encourage their *moral imagination*, and, third, to help them recognize the ethical and social issues that might be relevant." The guideline suggests building a rapport with the SDP team first, then to ask questions about their project, and finally to explore ethics issues in the project.

Data Collection

As explained in the General Project Design, there is a difference between the first-year pilot study and the second-year full term study. In the first year, four SDP teams volunteered to participate in our research project. Addressing ethics issues in the SDP poster presentation was a requirement, but ethics discussions were an extra activity, not a requirement. The observation and video-recording of these SDP teams occurred during the spring semester, i.e. the second semester of the SDP course. The four SDP teams were asked to discuss ethics issues twice and were randomly assigned to two conditions. Two SDP teams in the control condition discussed ethics issues twice without an ethics advisor. Two SDP teams in the intervention condition discussed ethics issues without an ethics advisor first, and for their second ethics discussion, an ethics advisor joined them. The ethics advisors were students from the philosophy of science and technology course, who volunteered to participate in the project. The length of the discussion is from 20 to 40 min. At each discussion, one of our research team members observed the discussion while taking field notes and video-recordings with two cameras. The observer explained the research project and obtained informed consent at the beginning of the discussion but did not participate in or facilitate the discussion.

In the second year, the ethics advising design was changed, as explained in the section "Ethics Advising Design" of this paper. Furthermore, there was a change in the SDP course. Ethics discussions became a course requirement, and all SDP teams needed to conduct four ethics discussions, two discussions in the first semester and two discussions in the second semester. The SDP teams began the first discussion usually a month after the semester started and did the second discussion 4–6 weeks later. The same pattern was repeated in the second semester. The SDP teams scheduled their discussion time at their convenience. Although ethics discussions were required course activities, participation in the research project was voluntarily based. Sixteen SDP teams participated in our engineering ethics research project, and nine teams were randomly assigned to the intervention condition and seven teams to the control condition. SDP teams in the intervention condition conducted all four ethics discussions with ethics advising teams. Each SDP team worked with two ethics advising teams because the philosophy of science and technology courses are one-semester courses. Pairing SDP teams with ethics advising teams was randomly done, but students' schedules were also considered. To help SDP teams engage in their ethics discussion, discussion prompts such as "What are the most important principles or ideas of engineering ethics?" and "What ethical questions or concerns does your project raise?" were constructed. In the first semester, all SDP teams in both conditions were provided with a worksheet containing question prompts and instructions to write a draft ethics statement for their presentations. SDP teams filled out the worksheet after the discussion and submitted it to the course instructor. In the second semester, specific question prompts tailored to each team's project were added. These prompts were provided only to encourage discussion, and SDP teams were informed that they could discuss any ethics issue beyond these prompts.

To observe and video-record ethics discussions, three teams from the intervention condition and three teams from the control condition were randomly selected for observation. A total of 24 ethics discussions from six SDP teams were observed and video-recorded. The length of the discussion varied from 20 to 80 min. Again, one of our research team members observed the discussion taking a field note and recording it with two cameras. At each discussion, the observer explained the research project and obtained informed consents, but did not participate in or facilitate the discussion.

Selection of Video Segments for Analysis

Thirty-two ethics discussion videos were collected from ten SDP teams. The video data were reviewed and ethics discussion episodes were coded in regard of professional, practical, and social contexts. The video data that show teams' concerns for social implications of engineering were annotated and transcribed. Ethics discussions were divided into segments, and descriptions of ethics discussion segments that show interaction between SDP teams and ethics advising teams were constructed. The length of each segment varied. The beginning of a segment was marked when a new issue was brought up to discuss or when a direction of the discussion was changed. The end of a segment was marked when another issue was brought up or a conclusion was reached. Several video segments in which ethics advising teams assisted SDP teams to engage, explore, or sustain their ethics discussion were identified. A few examples are described in Table 2. These examples are video segments of ethics discussions from three SDP teams that discussed ethics issues with ethics advising teams in the second year. The T-shirts Accelerating Robot (TAR) team designed a robot that launches T-shirts to the spectators at a sports event. The MicroPac (MP) team's project was to develop the proof of concept

Table 2 Examples of episodes that ethics advising teams help SDP ethics discussions

SDP team	Issue in discussion	Description of the segment
TAR	Ethical choice	SDP team discussed how their choice in engineering design makes a difference in efficiency of design process. Ethics advisors pointed out that design choice can be an ethical choice and making choices in engineering design is also an ethics issue. Both parties went on discussing what is an ethical design choice and what is not
TAR	User safety	Ethics advisors asked about an emergency shut-down process that can include a user's contribution. In this case, it was about designing a visible shut-down switch in the robot. SDP team accepted ethics advisors' opinions and discussed its implementation
TAR	Security	SDP team and ethics advisors showed different perspectives for wireless connection security. Ethics advisors concerned about dealing with accidental disconnection and the SDP team concerned about preventing intentional hacking. These differences led discussion in diverse directions
MP	Environments/health	Ethics advisors asked what would be the cleanup plan after the project is completed, such as how used materials, leftovers, wastes or the product is disposed, stored, or recycled. The SDP team admitted that they never thought about it. They discussed environmental safety and public health
MP	Social responsibility	SDP team mentioned that they do not think of social responsibility when they focus on engineering design, they just do their best with best intentions. Ethics advisors asked what the public means to them and the question of public good led to discussion of engineers' responsibility in weapons. The SDP team members have different opinions and could not find an agreement
SATA	Social responsibility	Encouraged by their previous discussion with ethics advisors, the SDP team searched for more information of potential ethics issues related to their project. First, the SDP team learned that their product can be used as electric evidence by digital forensics. It could bring many ethics issues to think about. Second, the SDP team learned that statistical analysis can have a lot of ethical issues. The SDP team said that this is good to know because they plan to do a user experience survey and statistically analyze it. Knowing the possible ethical issues involved in statistical analysis in advance is helpful to interpret the result

Table 3 Information on the selected video segments

SDP team	Condition/year	Issues in discussion	Peer ethics advising
Saber sound effects (SSE)	CC/year 2	User safety	No advisor
Helmet display (HD)	IC/year 1	User safety	Single advisor
T-shirts accelerating robot (TAR)	IC/year 2	User safety	Advising team

for motor control using SiC H-bridge. The SATA team's project was fabricating of a SATA Pass-Thru Disk Drive Controller.

To analyze how peer advising helps a SDP team engage and sustain their ethics discussion, segments that show ethics advisors helping a SDP team were collected. To analyze what conditions and environments supports peer advising, video segments that show discussions of similar issues in different ethics advising conditions were collected. Three video segments were selected for analysis. In these video segments, each SDP team discussed how to design a safe product for users, but each team discussed it in a different ethics advising condition. Table 3 shows the information about these three selected video segments. The TAR team's segment of discussing user safety was selected for the intervention condition with the ethics advising team. The Saber Sound Effects (SSE) team designed sound effects for an electric toy "laser sword." The SSE team participated in the second year of our study and discussed ethics issues without ethics advisors (control condition). The Helmet Display (HD) team designed a heads-up display system for a motorcycle helmet. This team participated in the first-year pilot study, and a student ethics advisor joined in their second discussion (single advisor intervention condition).

Data Analysis I: Cognitive Ethnography

Cognitive ethnography is a type of ethnography that focuses on the study of cognitive processes in sociocultural settings. Traditional ethnography usually focuses on the meanings that a sociocultural group creates. The observer who is placed within the group carefully observes what they create and interprets the meanings of it. Cognitive ethnography follows the steps of traditional ethnography, but the focus is on the process of cognitive activity that a group of people is doing. Instead of focusing on the meanings that the group creates, cognitive ethnography focuses on how the group creates those meanings (Williams 2006). This makes cognitive ethnography a useful method to observe and analyze how a group's cognitive activity, such as group discussion, is unfolding. Naturally, cognitive ethnographic methods combine traditional ethnographic methods, such as participant observation, interviewing, and artifacts analysis, with methods of cognitive science, such as process analysis or micro-analysis of specific practices and events (Alac and Hutchins 2004). The result of analysis is often presented as a narrative description or a cultural model. Cultural models represent ideas or practices which are shared within the observed cultural group (Fryberg and Markus 2007). Three selected video segments shown in Table 3 were analyzed through qualitative, micro-scale discourse analysis stemming

Index: **Bold: Safety,** *Italic& underline: Users*, Underline: Price, ***Bold & Italic: Engineer's actions***

A: That really comes down to, what are the **ethical** parts of *someone* that does have essentially, a **weapon**, and *someone* that has more of a **toy**.

B: Mhmm.

C: Yeah.

A: So...it's, like...

C: It's...*who* do you ***give*** that **responsibility** to? You ***don't give*** that **responsibility** to *somebody that's 5*.

A: Mhmm.

B: And with that, do you ***think it's better*** that they're ***charging*** a high price with it, because, like, with ours...it's - it's about to **hurt** *people.*

C: If a *kid* decided, "I'm gonna-"

B: You'll want, 'cause - *interrupted by C*

C: You'll wanna - If a *kid* was *weird* and...well, *not weird*...well, that would call myself *weird*. But, if you were one of those *kids*, it's like, "I want to find out how this works," and you **ripped it open** and you *didn't know what you were doing*, you could **kill yourself.**

B: Yeah...so that's what I'm saying, do you ***think it's better*** that we are ***charging*** a higher price with this.

C: I think so, yeah. Because it ***limits***...

B: Because it ***makes*** more...

C: ...It - it ***limits*** the *consumers* that can *buy* it. Because it's only the *people* that can *afford* it.

B: 'Cause then, *5-year olds, 10-year olds*, aren't gonna be the ones getting it. They're not gonna ask *their parents* for...

C: Yeah, and - and most, most *parents* are not going to *buy* a $400 lightsaber for their *5-year olds*.

Fig. 2 An example of analyzed transcription of the SSE team's video segment

from cognitive ethnography, and a cultural model that represents how a student team thinks of ethics issues in its engineering design project was identified in each case (Hutchins 1995; Kelly and Crawford 1997; Williams 2006). Each segment was analyzed focusing on key-words, verbal and nonverbal cues, and connectives. Figure 2 shows an example of the SSE team's analyzed transcription. The SSE team discussed ethics issues without ethics advisors. In the selected segment, the SSE team discussed the possible danger of their design product when it is used by young children. In Fig. 2, the dialogue transcription is coded by key-words. For example, words in bold are key-words related to safety and words in italic and underlined are key-words related to users. These key-words are coded not only by their literal meaning but using the contextual meaning gathered from the larger SDP team discussion. The key-words of safety in this dialogue include "toy," "weapon," "responsibility," "ripped it open," and "kill yourself." The key words of users include "somebody that's 5," "didn't know what you're doing," and "kid." These key-words indicate that the SSE team thought that an important safety issue in their design project is young children who might misuse their product because their product is a sophisticated toy sword. Figure 2 shows only one of many steps of key-words coding, verbal and nonverbal cues, and annotation. After the coding and annotation, an interpreted transcription was produced and revised it by repeated re-examinations.

This analysis revealed the SSE team's resolution for a possible safety concern. The SSE team concluded that charging a high price would reduce risk because young children cannot afford it. This conclusion indicated that the team approached the safety issue from the perspective of the providers of the product. At first, the

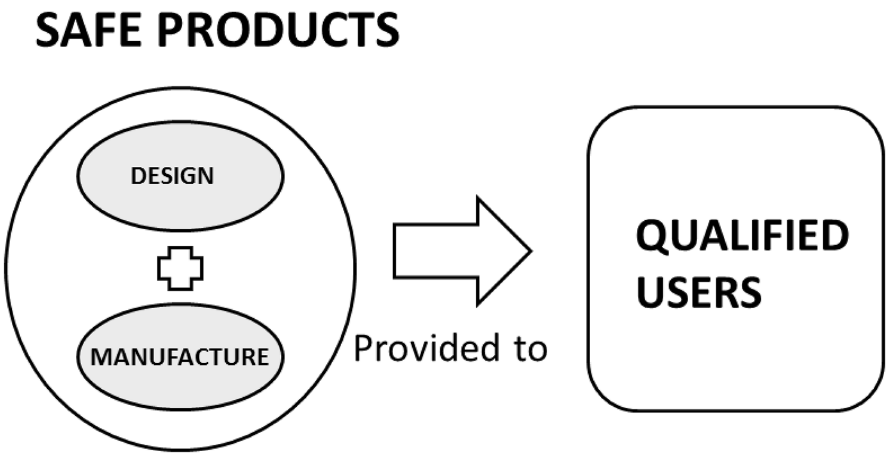

Fig. 3 Cultural model of the SSE team representing their understanding of safe design

SSE team was discussing the users' ethics and how they might see their product as a toy or a weapon. Then, they recognized that misuse by young children is an important safety issue in their design. Next, they came up with the idea of charging a high price and concluded that it would deter young children from obtaining the product. The SSE team seems to think that they are the agent who takes control of any action in this matter. The key-words related to engineer' actions in Fig. 2 include "give," "don't give," "charging," "think it's better," and "makes." These key-words indicate the idea that the users are recipients, and engineers are providers who control the safety issues. Their main idea is "*If a safe product is provided to the qualified users, the possible safety issue could be resolved,*" so they should find a way to secure safety of the product by providing it only to qualified users. In this case, qualified users are adults, and the way to secure safety is charging a high price for the product. To represent how the SSE team thinks and approaches to this concern, a cultural model was developed as seen in Fig. 3.

Data Analysis II: CHAT Analysis

After a cultural model of each team was identified based on the cognitive ethnographic analysis, each team's discussion was analyzed again, based on the CHAT framework. While a SDP team's discussion is considered as a cognitive activity during the cognitive ethnographic analysis, each SDP team's discussion is considered as an activity system during the CHAT analysis. In fact, it depends on how to view a team discussion, from the point of a process or from the point of a system. Unlike the cognitive ethnographic analysis focusing primarily on the SDP team's dialogues, this time the discussion activity was analyzed in terms of agents, actions, and settings. Seven elements of CHAT triangular diagram were mapped to features of each discussion activity; SDP team as the subject of the activity, the purpose of the discussion as the object of the activity, and the

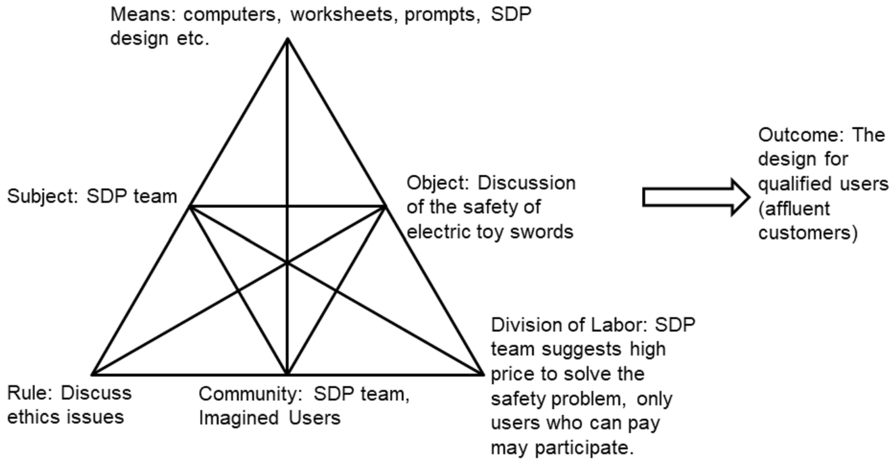

Fig. 4 CHAT analysis of the SSE team's discussion activity

conclusion of the discussion as the outcome of the activity. Then a CHAT triangle for each discussion activity was created to model the interconnections.

Figure 4 shows a CHAT triangle of the SSE team's discussion. The top part of the triangle represents the basic, three-way relationship between subject, mediating artifacts (means), and object in the discussion activity. The subject who acts is the SSE team, and the object of the action is to discuss safety issues in their engineering design project. The mediating artifacts include computers, worksheets, prompts, and the project design. The mediating artifacts are material or intellectual tools that the subject uses to achieve object. In the SSE team's case, the team used their computers to find resources and to write their documents during the discussion. Additionally, ethics discussion worksheets and general discussion prompts provided by the course instructor became the mediating artifacts. The team's engineering design was also an important mediating artifact. The bottom part of the triangle represents additional elements to construct the discussion. In the SSE team, the rule of the discussion was simply discussing ethics issues of the team project. Because the SSE team had no ethics advisor, they did not need a complex rule of interaction. Their community involved in the discussion consisted only of the team and their imagined users. The division of labor in this discussion included the SDP team and qualified users. What the SDP team did was to suggest a high price for the design product to solve safety issues; the team imagined that only qualified users would be able to afford the high-priced product, and thus that they would use the product safely. The outcome of this discussion was the engineering design for those qualified users.

This CHAT triangle shows a discussion activity in terms of agents, actions, and settings. This analysis helps compare different conditions of the discussion and identify what elements encourage or discourage the activity.

Index: **Bold: Safety**, ***Italic & underline: Users***, Underline: Team's opinions, ***Bold & Italic: Design process & product***

The Ethics Adviser (EA) is asking a question with hand gesture

EA: So.. as parents or grandparents may want *them* to be as **safe** as possible, get them this ***helmet*** ah… hoping that increases the **safety**….,but then, as a consequence, *he just wears* it all the time, *he hasn't* **develop**.. those **motorcycle skills** .. perhaps..

C: I just want to say.. I don't think it's ***an assumption*** at all.

A & B : As student C starts to speak, student A and B start to laugh silently.

Student C speaks with hand gesture and he emphasizes words "ridiculous" and "possibility". He speaks "it's ridiculous" three times.

C: Really, I just think it's ridiculous not ***designing*** this ***product*** because of possibility that *someone forgets* **how to look at the dash** , then you should say why….you know it's ridiculous…

D & E : student E mummer something, at the same time, student D burst into laugh

C: ….that you should start an automatic car, right?

Then *the vast majority of Americans* don't know **how to drive stick shift**.

What if we have any uphill that we can't drive non diesel cars that have automatic transmission, right?

At some point, you ***have to say okay***, you know it's just..

E: It's just a pop out possibility

C: yes, it's just… it's ridiculous.

Fig. 5 An example of analyzed transcription of the HD team's video segment

Results

Cultural Models

The SSE team's cultural model is described above, and the other two teams' cultural models are described in this section. The HD team that designed a heads-up display system for a motorcycle helmet participated in our first-year pilot study. A peer ethics advisor joined in their second discussion. In the selected segment, this team showed a very defensive attitude toward the ethics advisor. Figure 5 shows an example of key-words coded dialogue.

The dialogue below is a part of the HD team discussion in Fig. 5. When the ethics advisor suggested the possibility that some users might become overly dependent on this new device and possible safety concerns following from that dependence, the HD team saw it as a challenge aimed at stopping their project, and immediately tried to defend their design:

> **Advisor:** So.. as parents or grandparents may want them to be as safe as possible, get them this helmet ah… hoping that increases the safety…. but then, as a consequence, he just wears it all the time, he hasn't developed.. those motorcycle skills.. perhaps..
> **HD Team**: Really, I just think it's ridiculous, not designing this product because of possibility that someone forgets how to look at the dash(board), then you should say why….you know it's ridiculous…

Their responses, both verbal and nonverbal, revealed that the team thought that it is unlikely that this potential safety problem would occur. In addition to what a team member says, other team member bursts into laughter, showing non-verbal agreement to the word, "ridiculous" (See Fig. 5). In their view, even though this problem might impact a few unqualified users, it would not likely happen to most users. Only a handful of unqualified users, such as inexperienced drivers and "someone who

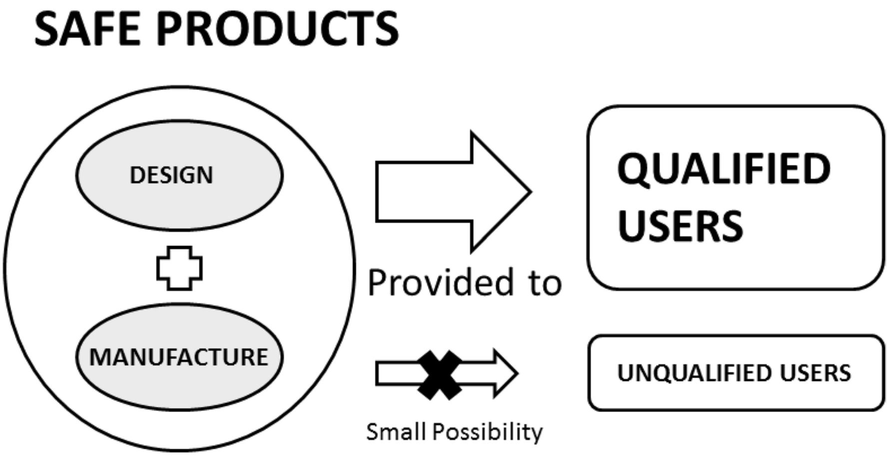

Fig. 6 Cultural model of the HD team representing their understanding of the safe design

forgets how to look at the dashboard," would cause this type of safety problem. In other conversations, the HD team also mentioned that it is the responsibility of the driver's license system to determine the users' qualification. Therefore, the concern raised by the ethics advisor was not a valid reason to stop their design project. They seemed to think in the way that "*engineers are providers, users are recipients*." If they design the product that is as safe as possible, and provide it to the *qualified* users, the safety issue will be resolved. In this way, their cultural model seemed to be similar to the SSE team's model. Figure 6 shows the cultural model of the HD team in regard of the safe engineering design for the users. Comparing Fig. 6 to Fig. 3, we can see the similarity between cultural models of the HD team and the SSE team.

The TAR team that designed a T-shirts launching robot participated in the second year and discussed ethics issues with an ethics advising team. In the selected segment, the team discussed the potential need for an emergency shut-down of the robot. Figure 7 shows a team dialogue transcription that is key-words coded with a non-verbal gesture.

It is noticeable that, at the ethics advising team's suggestion, the TAR team agreed to design a physical shut-down switch, so the operator or anyone nearby can stop it in an emergency situation. The team also mentioned that their initial solution would be to install the emergency shut-down software. The dialogue excerpt below shows the TAR team's response to the ethics advising team's opinion.

> **Advisor**: Ummm and besides the operator, I know there are only two operators, but will there be anyone actually physically able to like stop it if something does go wrong with it?
> **TAR Team**: What we might do also, is you know, if we talked about the emergency stop earlier, and I think you know, good practice is,… what you usually do is, you have, a… software…but then also you have a physical switch………. which you can run up and you know, pull the lever and it'll shut off, so we'll make sure to have one of those on there too.

Index: **Bold: Safety**, *Italic & Underline: Users*, Underline: Engineers' action, ( ): non-verbal expression

(The ethics advising team (E1, E2, & E3) and the SDP team (S1, S2, S3, & S4) are sitting at each side of the table.)

E1: Ummm and besides the *operator*, I know there are only *two operators*, but will there be anyone actually **physically** able to like **stop** it if something does **go wrong** with it? (While E1 is speaking, all SDP members are listening and smiling, looking at the ethics advising team)

E2: By a *second person*, or a **backup** that…

S1: That would probably be **wise**, yeah (S1 & S4 nod to each other, smiling; E3: mimicking martial art sound; They all laugh)

S1: What we might do also, is you know, if we talked about umm like the **emergency stop** earlier, and I think you know, good practice is,… what you usually do is you have, what… a… **software**…uhh like **emergency stop**, umm

S1: ….but then also you have a **physical switch** all over the robot which *you can run* up and you know, *pull the lever* and it'll **shut off**, so we'll make sure to have one of those on there too (S1 gestures with his hand to pull something; While S1 is speaking, S3 & S4 nod at him, and when S1 shows a hand gesture, S4 shows a similar hand gesture)

Fig. 7 An example of analyzed transcription of the TAR team's video segment

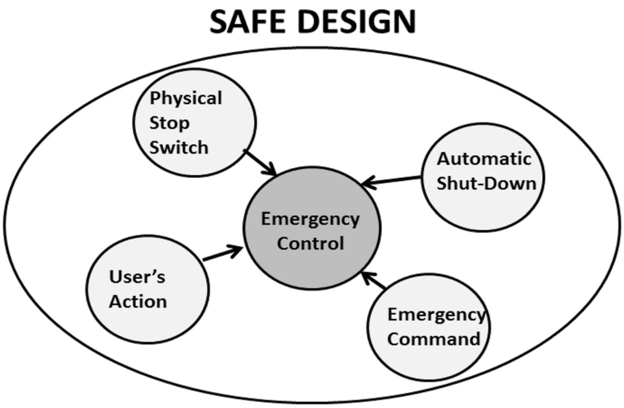

Fig. 8 Cultural model of the TAR team representing their understanding of the safe design

Although the TAR team thought of the software-based solution, they accepted the ethics advising team's suggestion and revised their design by adding a physical back-up plan. It indicated that the TAR team had a different cultural model from the other two teams in regard to the safe engineering design for the users. If the TAR team only used the software-based design, it would not have been much different from the other teams, offering a safe product to users. Unlike the other two teams, the TAR team included a user's role in the emergency stop process. As shown in Fig. 8, the TAR team's cultural model indicates that a safe design includes not only a design product but also an active role for the users.

CHAT Analysis

As shown above, cultural models in the TAR team's and the other two teams' discussions were different. To see what may have made such a difference, each team's discussion activity was analyzed based on cultural-historical activity theory (CHAT). The SSE team's CHAT triangle is described in the former section. Figures 9 and 10 show the HD team's and the TAR team's discussion activity in CHAT triangle, respectively.

The CHAT analysis of three engineering project teams' discussions revealed that the basic activity represented in three-way relationship between subject, mediating artifacts (means), and object was similar among the three teams. In all three discussion activities, the subject who acts was the SDP team and the object of the action was to discuss safety issues in the team project. The means that the subject used to achieve the object were almost identical in all three discussions. There was a difference, however, in the bottom part of the triangle. In the SSE team, the rule of the discussion was discussing ethics issues of the team project (see Fig. 4). The HD team's rule of the discussion was answering the ethics advisor's question. The team members did not exchange opinions among themselves, did not raise a question, and only focused on answering the ethics advisor's questions (see Fig. 9). In the TAR team, the rule of the discussion was collaborating to improve ethics aspect of their engineering design through the discussion. The team members of the TAR team exchanged opinions with ethics advisors and accepted some of ethics advisors' opinions (see Fig. 10).

In terms of community, there was a clear difference among three team discussions. Each case involved the SDP team along with an imagined group of users. The SSE team did not have ethics advisors, thus the community involved in the discussion was only the team and the users. In the HD team's case, the community consisted of the engineering project team, the imagined groups of users both qualified and unqualified, and the ethics advisor. In the TAR team's case, the community

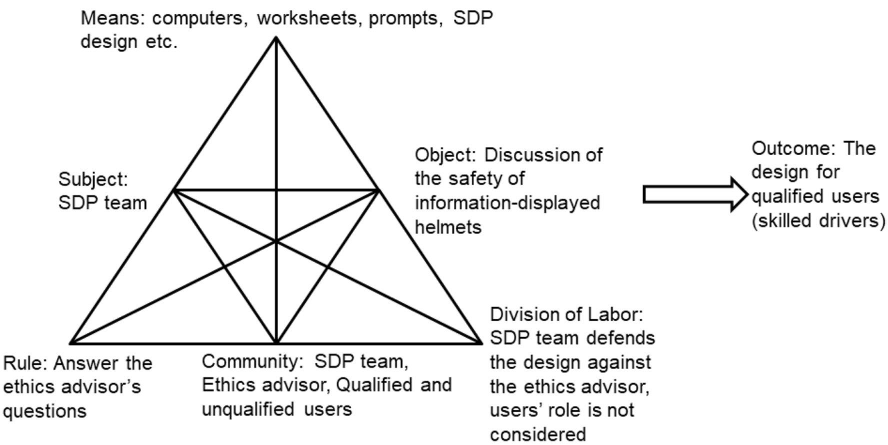

Fig. 9 CHAT analysis of the HD team's discussion activity

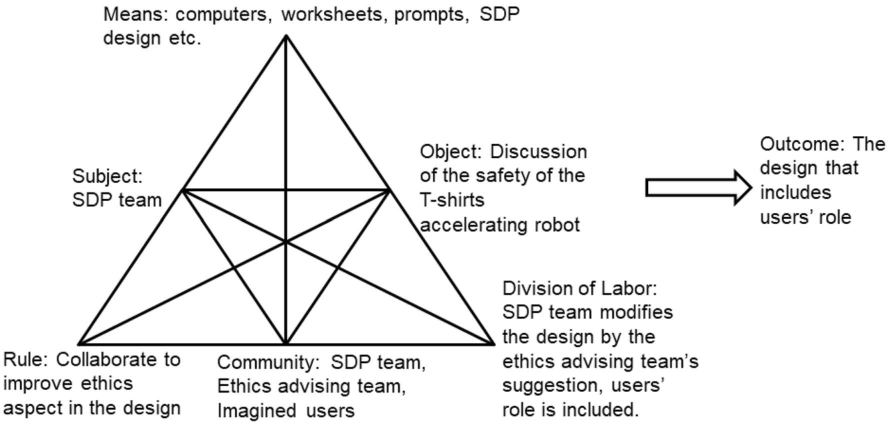

Fig. 10 CHAT analysis of the TAR team's discussion activity

consisted of the engineering project team, the ethics advising team, and the users. In terms of the division of labor, what the SSE team did was to suggest high price as a solution to the safety problem. The role of the imagined users was to accept it passively, if they could afford it, and to go without the product if not. In the HD team's case, the role of the HD team was to defend their design from the ethics advisor's questions. The HD team's defensive attitude indicated that this community is not in a collaborative atmosphere, but rather that the ethics advisor occupied an adversarial role. Although two imagined groups of users were a part of the community, they did not play any role. In the case of the TAR team, the TAR team's role was to modify their design in collaboration with the ethics advising team. The ethics advising team's role was to work together with the SDP team to improve the safety of the design, and the imagined group of users played a role to provide potential aid. Table 4 shows the difference among three teams in terms of a rule, community, and division of labor in CHAT analysis.

Discussion

Three SDP teams in this study were in different discussion environments. The SSE team did not have ethics advisors. The HD team had an ethics advisor, but the interaction between the team and the advisor did not help the team understand social implications of ethics issues; this may have been a result of the adversarial nature of the interaction. Based on this result, which occurred in the first-year pilot study, the ethics advising environment was changed. The TAR team discussed their design with the ethics advising team under this changed environment. The ethics advising team was not simply consulting with the SDP team, but they were also conducting their course project about ethics and values in engineering design, with a more directive structure aimed at generating collaboration. Therefore, both the SDP team

Table 4 Difference in rule, community, and division of labor among SDP teams

	SSE team	HD team	TAR team
Rule	Discuss ethics issues	Answer the ethics advisor's questions	Collaborate to improve ethics aspect in their design
Community	SDP team & imagined users	SDP team, ethics advisor, qualified & unqualified users	SDP team, ethics advising team, & imagined users
Division of labor	SDP team suggests high price as a solution to the safety problem. Users are supposed to passively accept high price	SDP team defends its design against the ethics advisor. Users' role is not considered	SDP team modifies their design in collaboration with the ethics advising team. Users' role is included

and the ethics advising team were helping each other in their projects as partners in collaboration.

Compared to the SSE team's discussion, the TAR team seemed to acquire socially broad understanding of engineering ethics issues as a result of the discussion. As engineers, they sought to make a technically safe design as much as the SSE team, but they also accepted the possibility that users' involvement may improve safety. It was revealed when they admitted that their original solution would have been software for emergency shut-down, but they would also consider a physical switch for anyone nearby to perform the emergency shut-down. The emergency shut-down process with a visible physical switch, often labeled as a Big Red Button, is not uncommon in engineering design. Although this modification was done following the ethics advising team's suggestion, the TAR team might have come up with this idea at some point even without the ethics advising team's comments. The noticeable point in this discussion is not the idea of physical emergency shut-down switch, but the exchange of opinions between two teams.[1] The TAR team showed willingness to consider the ethics advising team's suggestion that indicates the involvement of users in safety procedure. The physical switch in a robot is useful not only for operators and staffs but also for any bystanders. The SSE team also thought about the users' safety and tried to find a way to prevent possible dangers. The solution that they found was, however, to make their product expensive, because they thought that young users who may cause trouble or be in harm's way cannot purchase expensive toys on their own. Pricing is not usually an engineers' task, so the solution that SSE team found was not something they could actually do. Without outside input, however, the team members did not consider other options and continued the discussion based only on this option.

CHAT analysis was conducted to study what made a difference between these teams' discussions. According to CHAT analysis, the difference between these teams seemed to be related to their different micro-cultural context of the discussion activity. In the TAR team's discussion, the community included both the SDP team and the ethics advising team, and the rule of activity was to collaborate. On the contrary, the SSE team alone formed the community and the rule was to discuss within the team. This difference closely related to the different division of labor. In the case of the SSE team, the team played an active role, while the imagined users played a passive role. In the case of the TAR team, all the involved parties such as the TAR team, the ethics advising team, and the imagined users played active roles. Although the SSE team and the TAR team had similar elements of subject, means, and object, they had different elements of rule, community, and division of labor. The outcomes of these two teams are reflected in their cultural models of safety in design. The TAR team's outcome in their CHAT triangle was a design that included a role for users, and it represented the team's idea of safe design shown in their

[1] According to the instructor of their Senior Design course, however, this safety switch did not make it into their final product. This could be for any number of reasons, including time pressures and technical issues. Nevertheless, the observed impact on their ethical decision-making remains the phenomenon of interest.

cultural model. The SSE team's outcome was to design for qualified users (i.e., those who could afford the expensive product), and it also represented the team's cultural model about safe design. The interconnected elements of the CHAT triangle created a different micro-cultural context in each team's discussion activity, which resulted in different cultural models.

The influence of the ethics advisors, however, may not always be positive in social understanding of engineering ethics, unless it is carefully prepared. The HD team, though they had an ethics advisor, showed a similar cultural model to the SSE team. It indicated that the ethics advising did not influence them to acquire a broader understanding of social implications in engineering ethics. CHAT analysis revealed that, although the community for the discussion activity consisted of the SDP team and the ethics advisor, both parties were taking contradictory positions. The HD team considered the ethics advisor as an outsider who tried to raise objections to or identify problems with their design, so the rule of the discussion turned out to be: the ethics advisor questions, the SDP team answers. It limited the team's role to defending their design, while the ethics advisor inadvertently played an adversarial role. Comparing the HD team to the TAR team, the change made in the ethics advising environment seemed to create an effective, collaborative context for engineering ethics discussion. At the beginning of this study, it was expected that engineering student teams' ethics discussions with ethics advisors would be expert-guided activities that help engineering student teams understand ethics better in social context. The comparison between the HD team and the TAR team indicated, however, that a collaborative relationship between the SDP team and the ethics advisors is important for ethics advisors to help engineering student teams. As seen in the HD team discussion, the ethics advisor could have difficulty to be of any help to the SDP team if the SDP team and the ethics advisors did not create collaborative rapport first. When engineering ethics discussion becomes a cross-disciplinary, collaborative activity between two different expertise groups, they can explore engineering ethics that extends to social responsibility and understand diverse aspects of ethics issues in engineering.

Conclusion

In this study, three engineering student teams' discussions of the safety issue in different peer advising conditions were examined. It is expected that situated and expert-guided discussions may help students understand the social dimension of engineering ethics better, particularly about social implications of engineering ethics issues. As a result, different cultural models of safe design for users were identified in these three engineering student teams. According to these cultural models, the team that discussed in the collaborative ethics advising environment showed more advanced understanding of social implications of engineering ethics. Also, expert-guided engineering ethics discussion was not always fruitful as expected but needed to be supported by a collaborative environment between ethics advising teams and the engineering design teams. Therefore, we concluded that situated learning activities, such as ethics discussions in engineering design projects, can be benefited by cross-disciplinary collaboration between two groups rather than by expert's guidance from one group to the other or by engineering students working alone.

Understanding professional ethics is essential for future scientists and engineers. A situated and cross-disciplinary approach in engineering ethics education can help enhance students' understanding of professional ethics in terms of ethical integrity and social responsibility. Designing and implementing collaborative ethics education programs such as dialogue-based activities embedded in collaborative team projects may become a useful situated and cross-disciplinary approach. Nevertheless, it is too early to make any solid conclusions about the general effectiveness of peer ethics advising in engineering student projects based on this study, because the analysis did not aim at general effectiveness but focused on the process of peer advising in micro-scale, a specific moment of the discussion in three cases. In spite of this limitation, this study can add valuable information on two points. First, the findings can provide a type of pedagogical intervention template to design situated, dialogue-based, and cross-disciplinary collaboration activities in engineering ethics education. Second, encouraging collaboration between engineering design teams and embedded peer ethics advisors will facilitate the belief in engineers that ethical considerations are natural parts of the engineering design. It will also enhance engineering practice that includes dealing with various types of ethical concerns throughout the design process. A full-scale analysis of interventional effects will be required to provide detailed evidence on the general effectiveness of peer ethics advising. The development of relevant assessment techniques for such a larger-scale study will also be necessary. Despite the benefits of such a scaled-up study, more cases should be explored at the micro-scale as done in this study, because it will provide deeper understanding for effective interventions in engineering ethics education.

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