Exploring Implicit Understanding of Engineering Ethics in Student Teams

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Introduction

Given the importance of science and technology in our society, engineering plays a major role in many prominent social and environmental issues (Zandvoort, Borsen, Deneke, & Bird, 2013). In responding to such issues, engineering ethics is shifting its focus from merely preventing harm (both minor and catastrophic) to ensuring the social responsibility of engineering (Harris Jr., 2008; Zandvoort et al., 2013). Many have championed a new paradigm for engineering education that integrates strong, technical knowledge with real-world economic, ethical, social, and environmental concerns (Harris Jr., 2008;Volkwein, Lattuca, Terenzini, Strauss, & Sukhbaatar, 2004). Team-based projects and multidisciplinary applications that require collaboration with non-engineering students were also recommended (Volkwein et al., 2004).

As engineering education moves to engage with the social context of engineering and the social responsibilities of engineers, it must focus on the way that students understand engineering ethics and on whether and how engineering ethics will influence their decision-making in actual design processes. At present, engineering students appear to have relatively narrow and rigid views of professional ethics in terms of social context, as compared to business students, for example (Culver, Puri, Wokutch, & Lohani, 2013). Accurately gauging students' understanding of engineering ethics is a difficult task, because part of our understanding is intuitive or implicit; moral intuitions or intuitive ethics play an important role in students' understanding of engineering ethics (Haidt & Joseph, 2004). Also, learning and understanding can be situational and shaped by a culture of practice (Lave & Wenger, 1991), which suggests that it is necessary to study students' understanding of engineering ethics in actual design settings.

In this study, we observed teams of engineering students in design project settings discussing ethical issues that arise for their actual projects. We intentionally focus on teams over individuals, as they provide a more valid unit of analysis for understanding and improving the role of ethics in actual engineering practice. Furthermore, we organized and observed discussions with non-engineering students from a philosophy course who acted as "ethics advisors." We have observed interesting interactions that revealed important phenomena concerning students' explicit and implicit understanding of engineering ethics. These observations provide evidence that teams of engineering students tend to share a narrow explicit understanding of engineering ethics, suggesting that it may be learned in or as a byproduct of explicit instruction. Additionally, we noted that different teams' implicit understanding may or may not be in tension with their explicit understanding, suggesting that students bring a broad range of intuitive senses of social responsibility that could provide a potential resource for improving the ethical component of the education and practice of engineers.

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[1] This material is based upon work supported by the National Science Foundation under Grant No. 1338735.

Background: Implicit-Explicit Understanding in Engineering Ethics

When a person learns, understands, makes a decision, or thinks through a problem, two types of cognitive processes or systems are involved:

System 1 – *implicit*, unconscious, automatic, and works fast but is learned slowly

System 2 – *explicit*, conscious, effortful, controlled, and works slow but is learned quickly (Kahneman, 2011; Rydell, McConnell, Mackie & Strain, 2006).

In learning, these dual processes work for two different types of information. While conceptual information is obtained by fast-learning (System 2) processes, subliminal information is obtained by slow-learning (System 1) processes (Rydell et al., 2006; Nosek, 2007). System 2 learning is direct and declarative, while System 1 learning is mostly indirect and non-declarative. Students might learn conceptual knowledge taught in school by taking classes, but at the same time, they may learn subliminal knowledge that is not explicitly taught in school by socializing with school friends or from habits modeled by parents, teachers, and peers.

In making judgments, again, two types of processes are also at work; intuition comes first and reasoning comes second. Likewise, moral psychologists have argued that in moral judgment, intuitive processes precede explicit reasoning (Haidt & Joseph, 2004). Thus, when people make moral judgments, they may make a quick judgment based on intuition first, and then make a reason-based judgment. The different processes in cognitive activities can result in forming different types of understanding such as implicit understanding and explicit understanding (Nosek, 2007).

Engineering ethics involves moral concerns and judgment-making; therefore, we expect dual processes to be at work in forming implicit and explicit understanding about engineering ethics issues. Explicit understanding in engineering ethics is based on students' declarative knowledge, that is, what students explicitly state. It is also based on students' conceptual knowledge obtained by fast-learning System 2 processes. This type of understanding will form the basis of explicit reasoning when students make judgments. Meanwhile, implicit understanding in engineering ethics is based on students' non-declarative knowledge, that is, what students do not explicitly state but reveal through their actions, attitudes, and communication. It is also based on students' subliminal knowledge obtained by slow-learning System 1 processes. This type of understanding will likely be related to students' intuition.

These two different types of understanding will affect students' actions, attitudes and decision making in engineering ethics. If students implicit understanding and explicit understanding about a certain engineering ethics issue are similar, their actions or decision makings will be consistent; however, if there is a discrepancy between students implicit and explicit understanding, the effects on their decision making or actions will be complicated. A previous study by Rydell et al. (2006) reported that if subliminal information and conceptual information are opposed, there is tension in the evaluative process.

For the purposes of this study, we have chosen to observe students' relationship to engineering ethics by looking at how they engage in ethical reflection as a team, in the situation of their actual project work. This is an alternative to the more common approach of focusing on individual students and attempting to measure their understanding with an artificial instrument (such as a survey). We suggest that the dual-process account discussed above works as well for teams as for individuals. This study is thus firmly situated in the approach of "team cognition" (Salas & Fiore, 2004), "distributed cognition" (Hutchins, 1995), or "situated cognition" (Lave, 1988; Lave and Wenger, 1991), and the cognitive-ethnographic methods we apply follow from that approach. In real-world scenarios, such as engineering design, much of the work is performed by groups of individuals interacting with each other, mediated by tools and artifacts; thus, an adequate account of the moral judgments in engineering requires that we examine the group as the appropriate unit of analysis, not individuals considering hypothetical or historical cases by themselves in the classroom or laboratory. Furthermore, we move from analyzing the individual, where we can really only see the input and output of the cognitive process and have to infer the structure of cognition, towards analyzing the group, where the cognition itself takes place between individuals, making it more directly open to observation.

Methods

Participants

All engineering and computer science students at The University of Texas at Dallas are required to complete a team-oriented senior design project (SDP). The SDP requires students to employ a wide range of engineering knowledge and skill and gives practical experience in project management. SDPs are intended to closely conform to what students will experience as professional engineers.

All teams must complete a detailed written report and give two public presentations on their project. One presentation is a formal, verbal presentation with a power-point slide, followed by a brief question-and-answer session. The second is an informal poster session, lasting an hour or more, allowing for more drawn-out discussions. Both the written report and poster presentation are required to include an ethics statement, addressing potential ethical concerns related to the project.

For this study, we recruited four teams of students working on their SDP. Participation in the study was voluntary, and all participants were electrical, computer, or telecommunications engineering students. Each team consisted of three to five members, and each team conducted a different project of their choice. Each team consulted with a faculty mentor.

For our study, each participating team was asked to hold two discussions of ethics issues related to their projects as part of the planning for composing their ethics statement. For two of the teams, non-engineering students joined the second discussion with engineering students as "ethics advisors." These students were taking philosophy of science and technology courses and expected to guide engineering student teams to address relevant ethics issues.

Study Design

The study occurred over the course of one semester, and each of the four teams held two discussions approximately one month apart. All teams were randomly assigned into two conditions, one with the help of ethics advisors and the other without them. Table 1 shows the overall study design.

Student Team	First Discussion	Second Discussion
A	Team Only	Team Only
B	Team Only	An Ethics Advisor Joined
C	Team Only	Team Only
D	Team Only	An Ethics Advisor Joined

Table 1. Study design

Observation

All discussions were video recorded and observed by a researcher who took field notes. The observer did not participate in the discussion but observed students' discussions. The purpose of the observation was to obtain ethnographic data about ethical decision-making and moral judgment in natural settings, so students were encouraged to meet in the places they usually worked on their project and to discuss the ethics issues related to their own projects. The whole discussion was recorded with two video cameras, and both students' verbal conversations and non-verbal expressions were observed with note taking. In most cases, discussions lasted for approximately 20 to 40 minutes.

Data Analysis

Video data and field notes were analyzed through micro-scale discourse analysis based on cognitive ethnography (Hutchins 1995; Kelly & Crawford, 1997; Williams 2006). All the video data were reviewed and annotated to study the range of activity over time and identify key ideas. Then, a few exemplary episodes showing the team's understanding of key ideas in engineering ethics were selected for full transcription. Each episode was transcribed, and the text was examined based on logical connectives and key words. Based on the examined text, teams' explicit understanding was identified. Once explicit understanding was identified from the text, we prepared an annotated version of the text by adding words that indicate inferred meanings and describing the inferred meaning of non-verbal gestures and actions. We used these data to reconstruct the conceptual model to represent the teams' implicit understanding, and then we examine each whole episode again to refine the model. This model captures not the individual understanding of the several team members, but the micro-cultural model shared among them. Figure 1 shows an excerpt from one of the team's discourse. This team designed a shopping cart that can suggest possible recipes based on food items in the cart.[2]

[2] This case is described in more detail in the first part of the Results section below.

A: actually, this is really interesting question. Is it ethical that really, really looking good food there and have all the recipes and then sell some crappy food? (laugh)
B: we're not selling crappy food, we're just selling according to how good a cook you are…
C: yeah
A: yeah. after you make it, it doesn't look the same
B: no, but then eventually, if you keep trying, it will eventually look even better
D: even if it doesn't, it is truly not our problem, they can't....
A: it's your fault (laugh)
D: And that's like, whoever made the recipe, their fault that they put the picture that's not true to the recipe, so..
B: No, and you get the satisfaction you've made something yourself and you didn't get it take out from MacDonald or something.

A: actually, this is really interesting question. Is it *ethical* that really, really looking *good* (picture of) food there (on the screen of the smart recipe cart) and have all the recipes (suggested by the smart recipe cart) and then sell (it as) some *crappy* food? (laughing & hand motion of offering something)
B: we're not selling *crappy* food, (but) we're just selling (food with visual suggestion and possible recipes and the list of necessary ingredients), according to how *good* a cook **you** are.
C: yeah
A: yeah.(but). after **you** make it, it doesn't look the same (as food in the picture)
B: no, but then eventually, if **you** *keep trying* (to make) it, it will eventually look even better
D: even if it doesn't (look the same as food in the picture), it is *truly* not our *problem*, they *can't* (blame us for it)....
A: (Because) it's **your** (customer who makes it) *fault* (laugh)
D: And that's like, (and if there is anyone who is responsible for the inconsistency between the picture of the food and actual food), whoever made the recipe, their *fault* that they put the picture that's not true to the recipe, so.(it is their fault and they are to blame). (hand gesture).
B: No and **you** need to get a *satisfaction* (when) **you'**ve made something (cook food) **yourself** and **you** didn't get it take out from MacDonald or something (commercial product).

Note: Key project terms in underline, *ethically salient language in italics*, **references to users in bold,** (inferred meanings in parentheses), Non-verbal expressions in shade.

Figure 1. The excerpt from the team discourse (top) and the analyzed texts (bottom)

Results

Case I: The Smart Recipe Cart Team

The Smart Recipe Cart (SRC) team designed a tablet screen to attach to shopping carts that would suggest possible recipes based on items in the cart. The team had four members and held two discussions without an ethics advisor. During the discussions, they broadly discussed safety issues such as safe uses of batteries in their product, copyright issues such as sharing recipes with recipe providers, and security issues such as the theft or damage of the attached tablet screen. Moreover, this team discussed a few issues concerning social implications of their product such as the possibility of changing users' life styles by depending on their product, the potential impacts of encouraging users to purchase more food than planned by suggesting various recipes and the possible effect on users and grocery stores.

In the selected episode, the SRC team discussed one social implication issue in a particularly interesting way. One of the team members posed a question about their responsibility for the difference between food depicted in the suggested recipe and the actual food the user would produce. For instance, they discussed a possible situation where the picture that accompanied the suggested recipe was attractive enough to tempt users to buy it, but the result the customer got from making the recipe was disappointing. Would the team be ethically responsible for this outcome or not? As seen in Figure 1, the team pointed out that whether the result was satisfying and matched the depiction largely depended on users' ability to cook, so if the result was disappointing, it would have been mostly users' responsibility, saying, "It's your fault." Additionally, members of the team suggested that if there was serious discrepancy between the picture of food suggested in the recipe and the actual outcome of cooking that couldn't be attributed to user error, it would be the recipe providers' responsibility, because the recipe providers provided an unreasonable picture of the food. In this discourse, the smart recipe cart team explicitly stated that the responsibility went primarily to the recipe providers and then to the users, saying "It is truly not our problem, they can't (blame us for it)" and "Whoever made the recipe, their fault, they put the picture that's not true to the recipe, so (it is their fault.)"

The explicit meaning of the discourse does not exhaust the evidence of ethical consideration by the SRC team; several other elements of their discussion bear on the question of how they understood their ethical responsibilities. First, when discussing users, the SRC team referred to them with variations of the second-person pronoun "you." This language was unique habit in this team, as all other SDP teams we observed addressed users as "users," "customers," or using third-person pronouns like "him" or "they." Phrases such as "how good a cook you are", "After you make it, it doesn't look the same", and "If you keep trying, it will eventually look even better," indicated that they were imagining themselves in users' position while they discussed this matter. They discussed the responsibility issue as if they were giving advice to their friend, and even when they said, "It's your fault," it was said in friendly manner with laughing and teasing. This shows a level of empathetic identification with the user that bears on their understanding of the ethically salient relationships in this situation.

Second, they were not simply defending themselves to avoid responsibility, they were also seeking solutions for users. The team brought up the question of their responsibility for the discrepancy between the recipe and the outcome with interest, as seen in their discourse, "This is really *interesting* question. *Is it ethical* that really, really looking good food there and have all the recipes and then sell it as a crappy food?" The student who posed this question also made a gesture with his hands as if offering something (see Figure 2). The assertion that it was an interesting, ethical question, together with the offering gesture, and continuing conversation indicated that the team seemed to think the question was worthy of consideration. As compared to the team discussed in Case 2 below, the gestures and body language suggested that they were taking this concern seriously, rather than dismissing it. Although they tried to shift the responsibility to the users, they tried to suggest a possible solution for users at the same time, saying "But then eventually, if you keep trying, it will eventually look even better." Here, they appeared to be concerned about users' disappointment in an unsatisfactory outcome and suggested that their results would improve with consistent practice. It seems that their intention was not merely avoiding responsibility, but rather seeking a possible solution for both users and themselves.

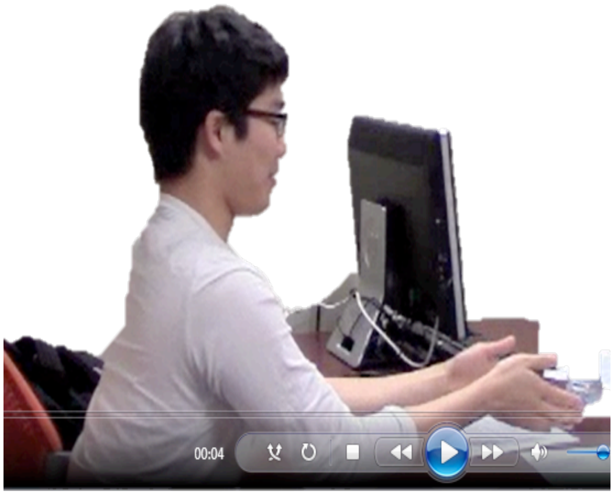

Figure 2. Hand gesture, offering up an ethical concern for discussion. SRC Team.

Third, the SRC team seemed to side with users rather than with the recipe providers who might become their business partners. In their conversations, they maintained an identification with users by addressing them in the second person, however, the team demanded responsibility from the recipe providers in an accusing manner, calling them “whoever made the recipe” and pointing out that it was the recipe providers who made the unreliable picture, saying “the picture that’s not true to the recipe.” It is often expected that business partners including designers, manufacturers, and marketers would take the same side, and the users or customers take the other side. In this case, however, the SRC team, who designed the product, seemed to be more in favor of users than potential business partners.

Considering these results, the SRC team exhibited an implicit understanding of some form of shared responsibility for the indirect outcomes and social implications of their engineering design. Although they explicitly stated that the responsibility for the discrepancy between the picture of food and the actual food is not their responsibility, and they tried to shift the responsibility to the recipe providers and the users, the SRC team showed an implicit understanding of a wider responsibility. Figure 3 shows a model of this understanding.

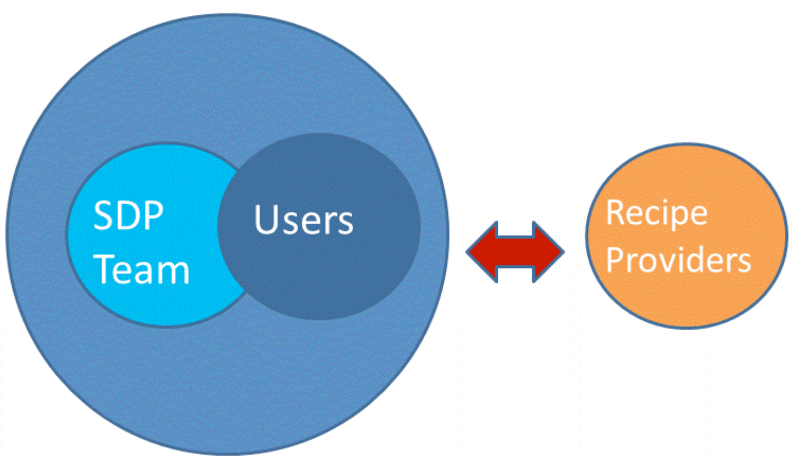

Figure 3. A model of implicit ethical understanding in the Smart Recipe Cart team

Case II: The Helmet Team

The Helmet team designed a “heads up” information display system for motorcycle helmets. By displaying necessary information such as speed and fuel level in the visor of the helmet, the driver need not frequently look down to the dashboard to check the information. The five-member team expected that this system would help the driver by reducing distractions. The Helmet team held two discussions about the ethics issues involved in their project. During the first discussion, the team discussed safety issues, security issues, copyright issues, and possible environmental issues. This team was particularly interested in legal complications such as patents and intellectual property rights. When trying to determine how to resolve potential ethical problems, the team largely relied on legal standards. For example, they mentioned that any danger related to users’ mistakes could be prevented if the exam for motorcycle drivers’ licenses was adequate to keep unqualified drivers off the road. Also, they mentioned that any environmental hazard related to their product could be prevented if they followed the applicable laws and regulations for environmentally safe materials. Unlike the SRC team, a student ethics advisor joined the Helmet team for their second discussion.

In the selected episode, the ethics advisor posed a question about the social implications of the helmet design. He asked the team to consider the possibility that a young driver who became overly dependent on the information display system may have not develop necessary driving skills for driving with a normal helmet or if the helmet failed. His question was met by the team’s disapproval and resistance. Verbal responses included “I don’t think it’s an assumption at all,” and “I just think it’s ridiculous not designing this product because of the possibility that someone forgets how to look at the dash.” The Helmet team appeared to think that they were not responsible for the indirect outcomes such as possible negative effect of over-dependence on the product and the possibility for not having developed necessary driving skills. They shifted the responsibility to the users in all such cases. Also, they seemed to think that this question, which covers the broader social implications of their design, was not relevant for them to consider.

Again, beyond the explicit meaning of their statements, there were several pieces of evidence that reflect the Helmet team’s implicit understanding of ethical responsibilities. First, the team’s attitude and affect during the discussion appeared to be defensive and protective of their design. The ethics advisor did not say anything to suggest they should not go through with the design their product, but the team automatically took the question as a challenge to the very existence of their design and tried to argue that the scenario described in the question could not be a relevant consideration of their design. Furthermore, the team dismissed the problem suggested by the ethics advisor as minimal and unimportant, saying “it’s ridiculous” to consider it. In fact, the word, “ridiculous”, was mentioned three times in this selected episode and emphasized to argue against the suggested question of social implications. Overall, the Helmet team showed defensive, protective, and dismissive reactions toward the social implication question posed by the ethics advisor.

Second, the Helmet team seemed to think only from the designers’ perspective. Unlike the Smart Recipe Cart team who addressed the users as “you”, the Helmet team addressed the users as the third party, such as “someone.” When the Helmet team used a word, “you”, it indicated themselves or other engineers, as seen in “You know it’s ridiculous”, and “You have to say okay.” The team seemed to assume that questions not directly related to engineering, such as social implication questions, were unhelpful to their design, so they tried to defend their design from the (perceived) unfavorable opinions of non-engineers. There was no indication that the team might see the problem from the users' perspective. Considering these results, the Helmet team seemed to think that issues not directly related to the technical requirements of engineering are irrelevant for their design, so they needed to protect their design from those irrelevant issues such as questions about social implications. Figure 4 illustrates the implicit cultural model based on the Helmet team's discourse.

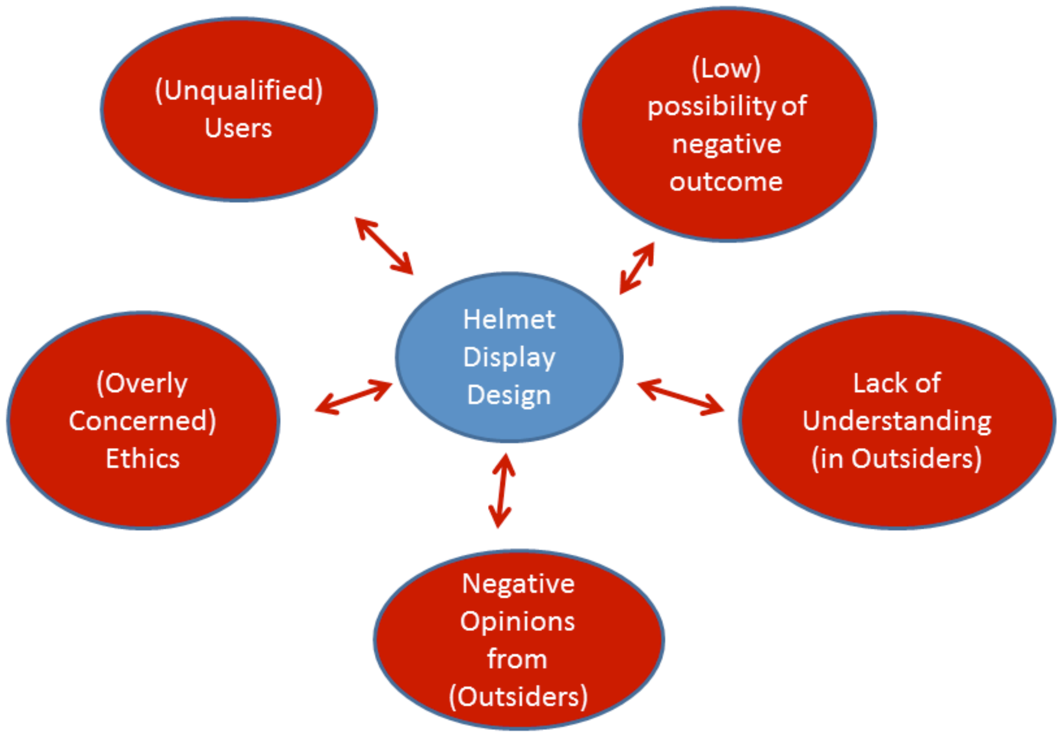

Figure 4. The model of implicit understanding in the Helmet team

General Discussion

Both teams' explicit understandings of their ethical responsibilities were similar, especially when it came to the social implications of engineering design. They stated that they were not responsible for these wider implications, and they shifted the responsibility to others, such as users. In the case of the SRC team, students said that the recipe providers would be primarily responsible for the discrepancy between the pictures of cuisine and the actual food. They said that the users would also be partly responsible, based on their cooking skill, or lack thereof. In the case of the Helmet team, students said that the unqualified users would be responsible for developing any over-dependence on the product. In fact, all the participating SDP teams we observed demonstrated similar explicit understanding of social implications of engineering design. They took responsibility for the matters directly related to the adequacy of their design such as potential malfunctions and design flaws. Also, they were willing to share some responsibility for potential safety and environmental impacts and alter their design to avoid such problems. Nevertheless, they shifted some of the burden of such impacts to other parties who they believed to have primary responsibility. For example, the Helmet team argued that, as long as they used materials and parts certified to meet the appropriate environmental regulations, they did not need to devote much consideration to the environmental impact of their design. Figure 5 shows the model of *explicit* understanding found in the participating SDP teams.

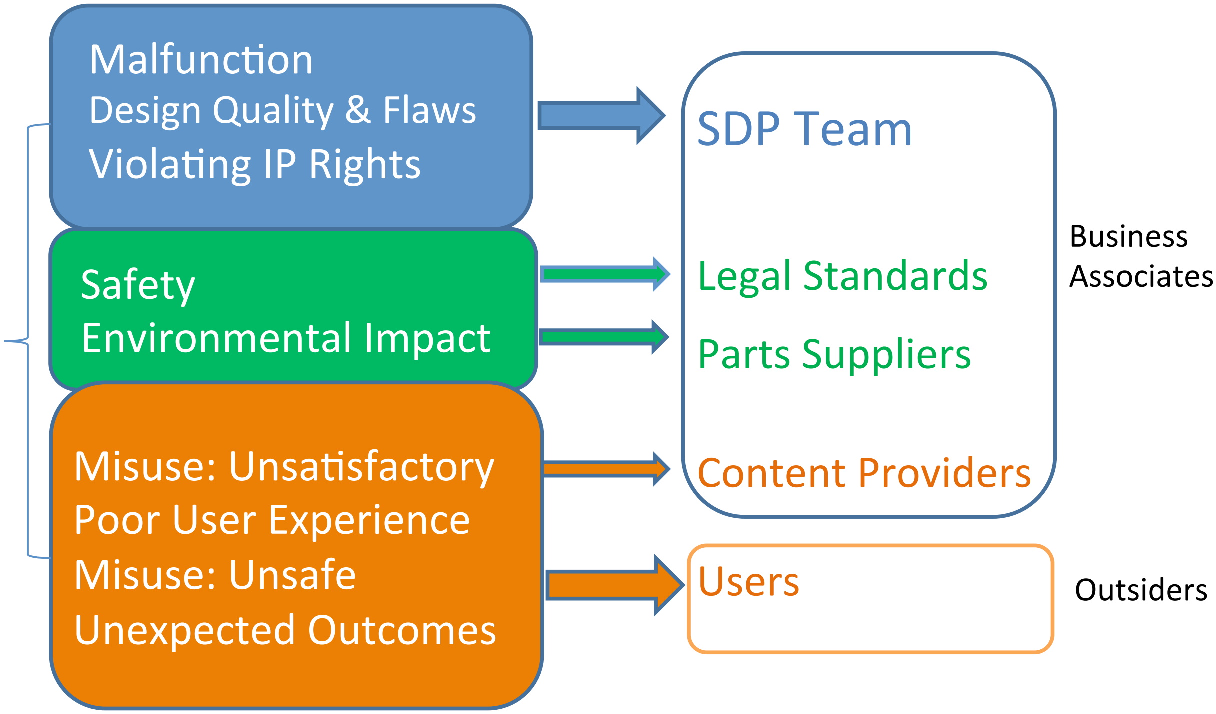

Figure 5. The *explicit* model shared by the SDP teams

As illustrated in Figure 5, students' explicit understanding of the responsibility varied according to the type of issues. For the technical issues directly related to the design, they took full responsibility. For the issues commonly recognized as related to engineering such as safety and environmental impact, they shared the responsibility. For the social implication issues such as misuse, poor user-experience, and unexpected outcomes, they shifted the responsibility to the third party, mainly the users.

It is important to note that students in SDP teams only recognized a narrow extent of engineering ethics and that all SDP teams showed similar explicit understanding. Previous work by Culver et al. (2013) that compared business students and engineering students for their understanding of professional ethics reported that engineering students showed relatively narrow and rigid views. The discrepancy was distinct in the issues of global difference, social and cultural implications, and the relationship between professional and personal ethics. The findings in this study support the previous findings, although engineering ethics has shifted its focus from preventive ethics to the social responsibility of engineering (Harris Jr., 2008; Zandvoort et al. 2013), engineering students' understanding of engineering ethics still focuses on the narrow view of ethics such as preventive ethics. Explicit understanding is based on the declarative knowledge and the conceptual information obtained by System 2 learning processes. Therefore, it is likely that students' explicit understanding is strongly related to what they learn in formal engineering education. Engineering students reportedly feel that they do not receive satisfactory ethics instruction through their curriculum (Culver et al., 2013). Cech (2014) reports a "culture of disengagement" in engineering education that may explain this shared, narrow explicit understanding. The findings in this study suggest that engineering ethics education needs to place more emphasis on the extended context including social, cultural, and global implications.

Unlike the explicit understanding that was largely shared across the SDP teams, there were substantive differences in the implicit understanding exhibited between the SRC team and the Helmet team. The SRC team, while sharing the narrow understanding of their responsibilities exhibited by other SDP teams in their explicit statements, also exhibited an implicit understanding that they shared some responsibility for the broader implications for the users. Moreover, they demonstrated that they were empathically close to the users. This indicates that there was a tension between explicit understanding and implicit understanding in the SRC team. Implicit understanding is based on the non-declarative knowledge and subliminal information obtained by slow-learning System 1 processes. If subliminal information and conceptual information conflict, there is tension in the evaluative process, which makes evaluation inconsistent and complicated (Rydell et al., 2006). The SRC team seemed to exhibit some implicit understanding of social context in engineering ethics, but it may not be easy for them to make a decision based on that alone or to apply their understanding in their actual design process, because there would be tension between their implicit understanding and explicit understanding.

On the other hand, the Helmet team did not show the same contradictory tendencies in their explicit and implicit understanding. Both their explicit understanding and implicit understanding focused on the narrow individual or professional dimension of the technical requirements of good design (Basart, & Serra, 2013, Herkert, 2005). The Helmet team's implicit understanding did not extend to awareness of the social context of technology, socially responsible engineering, or commitment to the public good (Harris Jr., 2008). Moreover, as they showed in their implicit understanding, they seemed to have even more rigid and narrow view about engineering ethics than they explicitly expressed. Not only did they shift responsibility for the indirect outcomes of their design to users, but also they showed very defensive tendencies against opinions based on social context. Considering that implicit understanding is based on subliminal information, it may have come from some elements of their social and cultural environment beyond formal engineering education, which influenced students gradually and persistently.

Conclusion

In this study, we examined the implicit and explicit understandings of engineering ethics, particularly the range of ethical responsibilities of engineers, in teams of engineering students working in their project-based "senior design" course. We found that the dual process account normally applied to individual cognition could also be seen in the distributed cognition of engineering teams. Further, we identified a case where the two processes were in tension. Given the importance of teams in many fields, how these processes work in teams engaged in shared cognitive activity, such as ethical decision-making and moral judgment, is an important area of future study, as is the impact of tension or agreement between the implicit and explicit levels of understanding on the effectiveness of group cognition

As seen in each cultural model presented in this study, these layers of understanding in engineering ethics may have various sources from the micro-culture of the SDP team to the cultures of the engineering profession and further, to the society at large. Implicit understanding seems to be under the influence of diverse sources, while explicit understanding seems to be closely related to formal engineering education. Nevertheless, there needs to be further exploration of various sources of the explicit and implicit understanding of engineering ethics.

Finally, understanding these complicated layers and their development may become an important resource for educating students to be socially responsible engineers. Engineering ethics has been shifting its focus from preventive ethics to social responsibility of engineering (Harris Jr., 2008; Zandvoort et al., 2013) and from the individual dimension to the social dimension (Basart, & Serra, 2013, Harris Jr., 2008; Herkert, 2005); thus, engineering ethics education needs to respond to the ongoing change. Engineering ethics education should take into account the multiple layers in students' understanding of engineering ethics, and ethics education should make use of these levels in shaping future engineers. We need to understand the forces that shape the explicit understanding of ethics demonstrated by engineering students, and we need to understand how a broader range of implicit understanding that students bring to the table can be used as a resource for more effective ethics education.

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