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ORIGINAL PAPER

The Roles of Implicit Understanding of Engineering Ethics in Student Teams' Discussion

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Abstract Following previous work that shows engineering students possess different levels of understanding of ethics—implicit and explicit—this study focuses on how students' implicit understanding of engineering ethics influences their team discussion process, in cases where there is significant divergence between their explicit and implicit understanding. We observed student teams during group discussions of the ethical issues involved in their engineering design projects. Through the micro-scale discourse analysis based on cognitive ethnography, we found two possible ways in which implicit understanding influenced the discussion. In one case, implicit understanding played the role of intuitive ethics—an intuitive judgment followed by reasoning. In the other case, implicit understanding played the role of ethical insight, emotionally guiding the direction of the discussion. In either case, however, implicit understanding did not have a strong influence, and the conclusion of the discussion reflected students' explicit understanding. Because students' implicit understanding represented broader social implication of engineering design in both cases, we suggest to take account of students' relevant

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implicit understanding in engineering education, to help students become more socially responsible engineers.

Keywords Engineering ethics · Implicit understanding · Intuitive ethics · Ethical insight · Cognitive ethnography · Distributed cognition · Situated cognition · Situated learning

Introduction

Educating socially responsible engineers is one of the most important goals in engineering education, and educating for social responsibility requires developing the engineering students' *understanding* of the ethical and social issues that arise in engineering (Harris Jr. 2008; Zandvoort et al. 2013). Our previous study found that engineering students show two different modes of ethical understanding: explicit and implicit (Lee et al. 2015). Both explicit and implicit understanding of engineering ethics refers to what students understand their ethical and social responsibilities as engineers to be, and both are at work in their decision-making. However, while explicit understanding is demonstrated through students' declarative knowledge and explicit reasoning, implicit understanding works through their tacit (non-declarative) knowledge, and it is revealed, not in what students explicitly state, but through their actions, attitudes, choice of wording, and style of communication (Haidt and Joseph 2004; Rydell et al. 2006; Nosek 2007; Kahneman 2011).

The teams of engineering students we have studied tended to share a narrow explicit understanding of engineering ethics, while the teams' implicit understanding varied significantly. In some cases, there was a noticeable discrepancy between a team's explicit and implicit understanding, which may evoke tension or conflict in that team's decision-making or problem-solving activities with regard to engineering ethics issues. For example, if a team's explicit understanding of engineers' responsibility is conceived in narrow terms, but demonstrates implicit understanding about engineers' social responsibility in a broad way, it is not easy to predict which type of understanding would influence the team's final decision about their ethical responsibilities or their final design decisions. In other words, it is not obvious that only explicitly stated understanding will play a decisive role in ethical decision-making.[1]

Our current study focuses on how the student teams' implicit understanding influences their decision-making and problem-solving processes, during team discussion of engineering ethics issues. Among the participating student teams, we selected two that showed noticeable discrepancies between implicit and explicit understanding. It was interesting that both of these teams demonstrated broad social understanding about engineering ethics in their implicit understanding, but not in their explicit understanding. To see how these teams' implicit understanding influenced their decision-making, and what role their implicit understanding played

[1] Throughout this article, we use the terms "ethical" and "moral" interchangeably.

during the discussion, we followed each team's discussion process, comparing it to Reif's account of the systematic problem-solving process (2008).

Our previous study suggests that student teams' understanding of engineering ethics may have various sources, from the micro-culture of the team to the culture of the engineering profession and further, to society at large. Formal engineering education seems to be the primary source of explicit understanding (Culver et al. 2013; Cech 2014), considering that the explicit understanding is usually demonstrated through declarative knowledge and reasoning. Meanwhile, various sources such as micro-cultures, informal education, and personal experiences seem to be involved in implicit understanding, and they are usually demonstrated through actions, attitudes, choice of wording, and style of communication (Haidt and Joseph 2004; Rydell et al. 2006; Nosek 2007; Kahneman 2011). The way that implicit understanding is demonstrated is similar to the way intuition or insight is demonstrated (Haidt 2001; Haidt and Joseph 2004; Roeser 2012). It is likely that the student teams' implicit understanding may play a role that is similar to intuition or insight in the decision-making or problem-solving process. In the current study, we identify two roles for implicit understanding of engineering ethics, exemplified by two cases. In one case, the team's implicit understanding played a role of *intuitive ethics* (Haidt 2001; Haidt and Joseph 2004), while in the other, it played a role of *ethical insight* (Roeser 2012).

Intuitive Ethics

The concept of 'intuitive ethics' is one of the two ways we analyze implicit understanding of ethical responsibilities. Haidt (2001) decries the domination of moral psychology by so-called "rationalist models," which give pride of place to the role of reasoning in moral judgment.[2] Throughout his work, Haidt has elaborated a contrasting view in which moral intuitions or intuitive responses are primary in moral judgment, a view he calls the Social Intuitionist Model (2001, 2007). By "intuition," Haidt, and other psychologists, generally mean a nearly automatic, immediate, direct response, quickly and effortlessly produced without conscious intervening steps or processes. "Moral intuitions" are intuitions that consist of or produce judgments that evaluate some action or the character of some person (including oneself or one's prospective or potential actions).

According to Haidt, moral reasoning usually consists in post hoc rationalization of the original, intuitive judgment, when it occurs. The purpose is not to improve or even support one's own moral judgments, but rather to influence other people, hence the "social" in "Social Intuitionist Model" (Haidt 2001). Haidt admits that there are cases where moral reasoning can override intuitive moral judgment, though he holds that these are rare phenomena. Greene et al. (2004), who also accept a two-systems view of moral judgment, provide fMRI data that putatively show cases where cognitive-focused brain regions are recruited to make judgments about difficult

[2] Note that this sense of "rationalism" in moral psychology is not the same as "rationalism" in philosophy, which holds that the relevant kinds of reasons are known a priori. The thesis Haidt calls "rationalism" includes (philosophical) rationalism, empiricism, sentimentalism, and pragmatism.

dilemmas, when the more cognitively-driven solution to the dilemma wins out. Haidt (2007) interprets this result as a case of reasoning overriding intuitive judgment. Although Haidt was originally very dismissive of the influence of reasoning over moral judgment, Greene and Haidt (2002) argue that moral reasoning plays a productive (rather than post hoc) role for "impersonal moral judgments and in personal moral judgments in which reasoned considerations and emotional intuitions conflict" (522), though Haidt (2007) still holds that such cases are rare. Contrary to Hadit's position, there are studies that present skeptical views on the role of intuitions in moral judgment (Bloom 2010; Kelly and Morar 2014; Prinz 2011). These studies argue that emotional intuitions are sources of bias in moral judgment. Notably, while Haidt argues that reasoned moral judgment just provides ad hoc justification for moral intuitions, and his critics argue that intuition is biased or worse than reasoned judgment, neither side seems to consider the possibility that reasoning might produce a less responsible, more problematic result than the original intuitive response.

Ethical Insight

'Ethical insight' is the second important concept for our analysis of implicit ethical understanding. In quite a few models of problem solving, insight is defined as a sudden, flash-like reaction—an "*aha*" moment—to a previously experienced impasse in a situation that requires a solution (for review of models, see Sawyer 2012). In such moments of insight, a solution to a problem emerges in a non-incremental way. In contrast to insight, the analytic problem-solving approach involves using well-known algorithms and incremental steps to reach the solution. While some researchers focus on the moment of insight in their studies (see Beeman and Bowden 2000; Metcalfe 1986), Weisberg and Alba (1981) show that insight is also related to a problem solver's experiences, knowledge, and cognitive-analytic processes (see also Lung and Dominowski 1985; Fleck and Weisberg 2004). Weisberg (2006) argues that insight can be used in problem-solving as a part of a cognitive-analytic process. According to him, insight does not act "out of the blue" to produce the solution but acts as a source of guiding information to restructure the problem in a certain stage of the cognitive-analytic process. In this way, insight can be involved in solving various types of problems.

Ethical insight can likewise be involved in ethics-related problem solving, guiding cognitive-analytic problem-solving processes. For ethical insight, a problem solver's emotions or feelings need to be considered, because emotions and feelings are indispensable resources for ethical insight (Roeser 2012). Previous studies showed that emotions and feelings are important in the processes of moral judgment, risk perception, and ethical decision-making (Roeser 2006, 2012; Finucane 2012). These studies showed that, and how, emotions influence judgment, decision-making and risk perception (Peters 2006; Finucane 2012). Three roles of emotions emerged from those discussions: First, emotions act as guiding information in judgment or decision-making processes. Second, emotions guide attention during such processes. Third, emotions influence information processing by guiding how to approach or avoid the decision-making task. There are also studies demonstrating that emotions may not be helpful in moral judgment. Prinz (2011) suggested that empathy can be biased and even harmful in moral judgment. Kelly and Morar (2014) suggested that a certain emotion, such as disgust, should not be used in moral judgment. Nevertheless, whether the role of emotions is positive or negative, it is possible that emotions are at the root of moral judgment (Bloom 2010), through their supportive role to reason (Pizarro et al. 2006). Considering all these possible roles of emotions in judgment or decision-making, and the close relationship between emotions and ethical insight, we propose that ethical insight plays a similar role in solving problems related to ethics, as emotions play in ethical judgment.

Situated and Distributed Cognition

Unlike the work of the moral psychologists cited above, our study adopts the perspectives of *situated* and *distributed cognition* (Lave 1988; Lave and Wenger 1991; Hutchins 1995). Whatever the importance of laboratory, classroom, and neuroimaging studies to our understanding of cognition and behavior, most human activity takes place outside of the lab, under very different conditions. Thus, in order to get a robust picture of cognition as it occurs in daily life, and to provide an important check on the ecological validity of the aforementioned types of studies, it is important to study cognition "in the wild" (Hutchins 1995). Such cognition takes place in rich settings containing many culturally constructed artifacts and structures, as well as social interaction. To ensure that what we learn in the lab matches cognition in practice, it is important to study cognition under natural conditions.

Haidt and many other contemporary moral psychologists hold that moral judgment or ethical-decision[3] making are social, interpersonal processes, that moral behavior and moral reasoning both evolved to help us navigate and manipulate a dense, difficult social space (Haidt 2001, 2007). Yet the research they do still adopts methodological individualism in an artificially contrived laboratory situation, testing the moral judgments and reasoning of individuals to arbitrarily specified thought experiments. Even social psychological experiments treat the subjects interpersonally, as separate, atomic reasoners interacting with one another, rather than as a team engaged in a socially shared activity. We instead adopt a situated, distributed approach to overcome these limitations.

This approach is important in the case of engineering research and design, and the ethical decisions made therein, because such decision making is often the responsibility of teams of engineers, distributing tasks socially, and it is always undertaken in specific situations of practice, using complex tools. As such, the attribution of responsibility for ethical decision making to single persons inside a larger system of socially situated and distributed activity runs into serious empirical and conceptual problems (Galison 2000; Holden 2009). Engineering education, because of its focus on problem-based learning at the undergraduate level and experience in laboratory work at the graduate level, already displays a tacit

[3] Different psychologists and philosophers prefer one or the other of these phrases, but we see them as getting at the same thing, and so use them interchangeably.

commitment to the situational approach, but this approach has not been translated to treatments of engineering ethics, or engineering ethics education.

Methodologically, the primary way to approach the study of situated, distributed, cognitive activities is the qualitative, observational method of *cognitive ethnography* (Hutchins 1995; Williams 2006). Cognitive ethnography employs many of the same skills and practices as traditional anthropological ethnography, but combines them with the analytical techniques of contemporary cognitive science as well as digital recording and analysis tools. Cognitive ethnography is focused more on the functional description of cognitive activities, rather than cultural processes more broadly. As Williams (2006) puts it, “Whereas traditional ethnography is concerned with the meanings that members of a cultural group create, cognitive ethnography is concerned with how members create those meanings.” Cognitive ethnographic methods can be used to construct more ecologically valid experiments, and it can also be combined with quasi-experimental interventions into the situations of interest themselves, as we have done in this study.

Methods

General Study Design

This study was a part of a 3-year project to explore and improve engineering students’ understanding of engineering ethics. All undergraduate engineering students at our study site are required to complete a team-based senior design project (SDP) to build and demonstrate their knowledge and skills through practical design experience. We followed these undergraduate research and design teams for their yearlong design projects, observing team discussions about ethics issues involved in their projects. Understanding of engineering ethics is a part of the SDP requirements, and students are required to demonstrate how they take account of engineering ethics in their final presentations.

The research was conducted for two consecutive years following total of 20 SDP teams. In the first year, four SDP teams participated in the pilot study during the spring semester. For each team, we organized two team discussions about ethics issues involved in their own project. The teams were randomly assigned to two conditions. Two teams discussed on their own, while two other teams were joined by a philosophy student who acted as an ethics advisor in their second discussion. In the second year, 16 SDP teams participated for two consecutive semesters. For these teams, we organized four discussions, two for each semester. In the second year, participating teams were also randomly assigned to two conditions. Instead of introducing a single ethics advisor, we introduced an ethics advising team that consists of a group of philosophy students. Thus, nine teams were joined by ethics advising teams in all of the discussion, while seven teams discussed the ethics relevant to their project on their own. All participations were voluntary, and the research was conducted under Institution Review Board (IRB) approval.

This research project has two distinct purposes. First, we have observed engineering student SDP teams under these conditions, using cognitive-ethnographic methods, to collect a rich set of qualitative data, to create a better understanding of the fine-scale processes of situated group cognition around solving problems in engineering ethics; this is the data that we report and analyze in this paper. Second, we are attempting to assess the intervention, to determine whether introducing ethics advisors from a philosophy course effectively improves the quality of ethical reasoning and decision-making in SDP teams; these results will be discussed in detail in future publications.

Data Collection

We observed discussions from ten randomly selected teams, took ethnographic field notes, and video recorded the 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. Teams were required to work as a group to complete a worksheet with questions that asked them to identify potential ethical issues arising in their own design project and how they might make design choices to account for those issues. We recorded the whole discussion using two video cameras, and we did not prompt or facilitate the team discussion. Student teams' discussions lasted for 20–40 min.

Data Analysis I: Cognitive Ethnography

Video data and field notes were analyzed through qualitative, micro-scale discourse analysis based on cognitive ethnography (Hutchins 1995; Kelly and Crawford 1997; Williams 2006). Cognitive ethnographic research combines traditional ethnographic methods, such as participant observation, interview, and artifacts analysis, with micro-analysis of specific occurrences of events and practices to conduct fine-grained analysis of cognitive processes, usually using digital tools (Alac and Hutchins 2004). To analyze the video data, we reviewed and annotated the body of video in conjunction with field notes. Then, we selected video segments that show the teams' understanding of key ideas in engineering ethics. The selected video segments were transcribed, and the text was examined in terms of logical connectives and key words. Based on this text data, we identified the team's explicit understanding of engineering ethics. Then, we further annotated the transcript by adding words that describe pauses, gestures, and other non-verbal actions. We also added words that indicate inferred meanings to prepare for the interpreted version of the transcript. We examined the annotated transcript as well as the interpreted transcript to identify the teams' implicit understanding of engineering ethics.

Data Analysis II: Systematic Problem-Solving Processes

Next, we examined the annotated transcript based on Reif's (2008) account of systematic problem-solving processes to see how the team discussions were conducted. Reif (2008) suggests that the basic systematic problem-solving strategy consists of five repeatable phases. Although no strategy guarantees correct solutions to all problems, some strategies can provide systematic approaches that can facilitate their solutions. The basic problem-solving strategy for systematic problem solving is one such strategy, and it can help facilitate an effective use of knowledge, which makes it useful in science and engineering fields (Reif 2008). Table 1 briefly describes the basic problem-solving strategy for the systematic approach. We examined each team's discussion transcript based on the basic systematic problem-solving strategy to see the structure of the discussion over a small time-scale. Then, we reexamined the structure of the discussion to see at which step of the discussion, and in what way, the team's implicit understanding influences the discussion.

Sample Selection: Saber Sound Effect Team and Smart Recipe Cart Team

The participating teams tended to show a narrow explicit understanding of engineering ethics (Lee et al. 2015). In the case of engineering responsibilities, for instance, student teams seemed to take full responsibility for technical or professional issues, though they hesitated to take responsibility for social values and impacts. Meanwhile, student teams' implicit understanding varied among the teams. Some teams showed little discrepancy between their implicit understanding and explicit understanding. For example, one student team designing an information displaying helmet for motorcycle riders demonstrated a narrow explicit understanding of engineering responsibility. They also showed a defensive attitude about their design product in their implicit understanding. Although there were differences between the implicit understanding and the explicit understanding in this team, these understandings were not in tension with each other (Lee et al. 2015).

There were teams, however, that had clear differences between their implicit and explicit understandings. To study the role of implicit understanding in student teams' ethics discussions, we looked for cases under the following conditions. First, we looked for cases of discussing social the implications of engineering ethics because how social responsibility is understood is an important issue in current

Table 1 The basic problem-solving strategy for the systematic approach (Reif 2008)

Action	Phase	Description
Repeated and revised	Describing the problem	Producing a clear description of the problem, contemplating the situation, specifying the goal
	Analyzing the problem	Putting the problem into a form facilitating the subsequent construction of the solution
	Constructing the solution	Attempting the solution, leading to the decomposition of the problem into chosen sub-problems
	Assessing the solution	Assessing the obtained solution, providing general criteria for checking the solution
Supplemented if necessary	Exploiting the solution	Exploiting the solution if further usages or ulterior goals beyond the particular problem are there

engineering education (Harris Jr. 2008; Zandvoort et al. 2013). Second, we looked for teams that showed conflicting implicit and explicit understandings about social responsibility of engineering ethics, so that we could see the influence of implicit understanding clearly. Considering these conditions, we selected two cases, one was a discussion by the Saber Sound Effects (SSE) Team, and the other was a discussion by the Smart Recipe Cart (SRC) Team. Interestingly, these two teams turned out to demonstrate a better understanding of the social responsibility of engineering ethics in their implicit understanding than in their explicit understanding.

Case I: Saber Sound Effects Team

The Saber Sound Effects (SSE) team was designing a sound effects system for a toy resembling a lightsaber. This team was not joined by an ethics advising student team, therefore their ethics discussions were not facilitated or prompted by experts. During the discussion in the selected episode, the team questioned whether charging a high price for a product with low manufacturing cost is ethical or not. Table 2 shows the annotated transcript of the discussion. In the beginning of the discussion, the team declared that doing so is unethical, but through the discussion, they modified their opinion. Finally, they concluded that, in some areas such as medicine, it is clearly unethical, but in other areas, it is difficult to decide whether it is ethical or not, because everybody has different moral priorities—the likelihood of moral disagreement seems to lead them to argue that there is no answer to the question of whether charging a high price in this case is ethically permissible or not. This conclusion represented this team's explicit understanding about this issue.

In their implicit understanding, however, the team seemed to disapprove of charging a high price. When the question was raised, they demonstrated their implicit disapproval by giving an instant response of "no." Table 3 shows a part of the interpreted transcript of the discussion.

The instant disapproving response was followed by silence to search for the reasons why it is unethical. Then they began to give reasons for their disapproval. Although the team eventually concluded that "it is in grey area, " they did not seem to completely give up their disapproving attitude. For example, they used words of less confidence in their concluding remarks, "I don't know. I think there's always grey…there's never a right and wrong" than in their former claim, "On the medicine side, there's definite, there's a definite right." Table 4 summarizes the SSE team's explicit understanding and implicit understanding about high price and low manufacturing cost issue.

According to Reif's (2008) model of the problem-solving process, the SSE team conducted the discussion following a systematic problem-solving process. First, the team described the problem. Next, they went through several phases, including problem analyzing and solution construction, repeating and revising each phase several times before making a final decision. The concluding judgment represented the explicit understanding that was stated in their conversation (see Table 5).

In the discussion process, however, the team diverged from Reif's (2008) account of basic systematic problem-solving processes in one respect. After describing the

Table 2 The annotated transcript of the SSE team's discussion

(Underlined: words related to ethics, *Italics: words related to engineering*, Shade: words related to price, **Bold: non-verbal,** ***Bold & Italics: words related to problem-solving*****)**
C: So, like, if you're paying $400 for something that costs somebody 10 cents to *make*, that's...
A: Right...
B: Yeah...
A***: Is that ethical?***

C: No.
A: Why?
(The students are silent for 5 seconds)

C: I mean, unless the *engineering time* to *develop* said thing that you can now *make* for 10 cents is so high that you have to charge $400 to break even, then ***there's not really a good reason*** to charge that much.
A: Right, so who's all -
C: And on top of that, if anybody discovers other *ways of making* that same *product* that are also just as inexpensive, they can still *compete* with the - much easier.

B: Okay, how do you feel about that with *copyrigh*t, then? 'Cause you know, when people like first *make medicines* or anything like that, they get like 20-year *copyright* where they're the only ones allowed to *make* it and they can sell it for whatever price they want, then...
A: Mhmm...
B: How do you feel with that, 'cause it keeps the whole supply and demand thing down, and...?
C: So, in the - in the realm of *medicin*e, charging $1000 for a *medication* that could save somebody's life is a ***little ridiculous.***

B: That costs...$5 -
C: That costs $5 to *make* and you charge $500 - ***that's not ethical*** because now you're putting somebody's life at risk.

B: What about if it's just a normal product, though?
C: Like, you say you -
B: Like, like, the *computer*, or -
C: Like, the first *iPhone* -
B: Yeah, the first *iPhone* is your -
C: Let's say the first *iPhone*, instead of costing $200 to *make*, costs only $10. And they charge $700 for it.
A: Mhmm.
B: Yeah. Yeah.

A: But what if - who's all the parties that are involved?
B: And are you saying that the customer doesn't have that free will?
A: Mhmm. Do you *need* that *phone*?
B: 'Cause they're the ones buying it. 'Cause I understand you on the medicine side, I'm more...

C: Yeah, on the *medicine* side, ***there's definite - there's a definite right...***
B: I think ***there's a lot more ethical*** (*difficult to hear),* but...
A: I don't know. I think ***there's always a grey - there's never a right and wrong***.

B: Yeah...Oh, yeah, no, no - I agree with that. I didn't think there's -
C: ***There's always - there's no...***when you're dealing with ethics, ***there's no...***'Cause everybody has different...prio- everybody prioritizes morals differently - like, somebody's like, "Oh, charge a fair price" is more important to them than...

problem, instead of going into the phase of analyzing the problem, the team constructed a solution first, "Is that ethical? No." In this way, the team's process looks more like the version of problem-solving inquiry described by Dewey (1933, 1938). Dewey describes initial recognition of a problem and suggestions for potential solution as coming almost immediately together. He is also clearer than Reif that it does not matter which phase of inquiry comes first; what matters is the way that the phases build off of each other in a process of iterative refinement.

Table 3 A part of the interpreted transcript of the SSE team's discussion

C: So, like, if you're paying $400 for something that costs somebody 10 cents to *make*, that's... A: Right...(understanding what C means though C did not finish the sentence) B: Yeah... (understanding what C means though C did not finish the sentence) A: ***Is that <u>ethical</u>?*** C: No. (immediately answers that charging $400 for something that costs 10 cents to make is not ethical) A: Why (is it not ethical)? **(The students are silent for 5 seconds)** (At this moment, A is acting like a facilitator who asks a question and waits for an answer, while B and C are trying to find an answer.)

Table 4 The SSE team's explicit and implicit understanding of an engineering ethics issue

Explicit understanding	Implicit understanding
In some areas such as medicine, charging a high price for products with low manufacturing cost is definitely unethical	The team intuitively disapproves of charging high price for product with a low manufacturing cost
In other areas, it is difficult to say because everybody has different moral priority	

After suggesting a solution, the SSE team assessed the solution by reasoning, "Why? … I mean, unless…," and began to analyze the problem. This tentative solution seems to come from the team's implicit understanding that high sale price relative to low cost of production is unethical. The discussion was continued as they repeatedly analyzed the problem with different examples and constructed tentative solutions. There was a turning point during the discussion, which turned their view of charging a high price for a product with low manufacturing costs from 'definitely unethical' to 'never a right and wrong.'

Case II: Smart Recipe Cart Team

The smart recipe cart (SRC) team designed a tablet screen that attaches to a shopping cart and can suggest possible recipes based on the items in the cart. Like the SSE team, the SRC team was not joined by an ethics advisory student team, therefore their ethics discussions were not facilitated or prompted by experts. In the selected episode, the team discussed responsibility for the possible discrepancy between the picture of the suggested recipe (which is likely cooked and photographed by professionals) and the final outcome obtained by a typical person cooking. Figure 1 shows the annotated transcript of the SRC team's discussion with an image captured from the video. According the transcript in Fig. 1, the SRC team stated that they are not responsible for the discrepancy, saying "it is truly not our problem," "whoever made the recipe, [it is] their fault," and "it's your [the user's] fault." They declared that the discrepancy depends on the users' cooking skill and

Table 5 The systematic problem-solving process analysis of the SSE team discussion

(Underlined: words related to ethics, *Italics: words related to engineering*, Shade: words related to price, **Bold: non-verbal,** ***Bold & Italics: words related to problem-solving*****)** C: So, like, if you're paying $400 for something that costs somebody 10 cents to *make*, that's... A: Right... B: Yeah... A***: Is that ethical?***	*Describing the problem
C: No. A: Why? **(The students are silent for 5 seconds)**	*Constructing the solution ("No") * Assessing the solution ("Why?)
C: I mean, unless the *engineering time* to *develop* said thing that you can now *make* for 10 cents is so high that you have to charge $400 to break even, then ***there's not really a good reason*** to charge that much. A: Right, so who's all - C: And on top of that, if anybody discovers other *ways of making* that same *product* that are also just as inexpensive, they can still *compete* with the - much easier.	*Assessing the solution (Reasoning to support the solution)
B: Okay, how do you feel about that with *copyrigh*t, then? 'Cause you know, when people like first *make medicines* or anything like that, they get like 20-year *copyright* where they're the only ones allowed to *make* it and they can sell it for whatever price they want, then... A: Mhmm... B: How do you feel with that, 'cause it keeps the whole supply and demand thing down, and...? C: So, in the - in the realm of *medicin*e, charging $1000 for a *medication* that could save somebody's life is a ***little ridiculous.***	*Analyzing the problem with an example
B: That costs...$5 - C: That costs $5 to *make* and you charge $500 - ***that's not ethical*** because now you're putting somebody's life at risk.	*Constructing the solution & assessing the solution
B: What about if it's just a normal product, though? C: Like, you say you - B: Like, like, the *computer*, or - C: Like, the first *iPhone* - B: Yeah, the first *iPhone* is your - C: Let's say the first *iPhone*, instead of costing $200 to *make*, costs only $10. And they charge $700 for it. A: Mhmm. B: Yeah. Yeah.	* **Turning Point** *Analyzing the problem with different examples
A: But what if - who's all the parties that are involved? B: And are you saying that the customer doesn't have that free will? A: Mhmm. Do you *need* that *phone*? B: 'Cause they're the ones buying it. 'Cause I understand you on the medicine side, I'm more...	*Analyzing the problem, considering stakeholders such as users
C: Yeah, on the *medicine* side, ***there's definite - there's a definite right...*** B: I think ***there's a lot more ethical*** (*difficult to hear),* but... A: I don't know. I think ***there's always a grey - there's never a right and wrong***.	*Constructing the solution
B: Yeah...Oh, yeah, no, no - I agree with that. I didn't think there's - C: ***There's always - there's no...***when you're dealing with ethics, ***there's no...***'Cause everybody has different...prio- everybody prioritizes morals differently - like, somebody's like, "Oh, charge a fair price" is more important to them than...	*Assessing the solution

the recipe providers are responsible for the discrepancy. These statements showed their explicit understanding about this issue. In their explicit understanding, the SRC team denied their responsibility for the potential, unintended, negative outcome of their design and shifted the responsibility to the users and the recipe providers.

(Underlined: ethically salient words, *Italics: key words related to the project*, Shadow: words addressing users, **Bold: non-verbal)**

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)**

(Hand gestures of offering something)

(Hand gestures of writing a list)

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

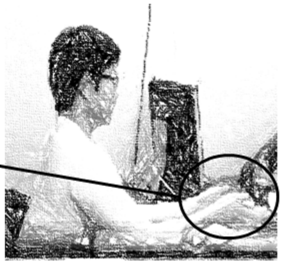
D: even if it doesn't, it is truly not our problem, they can't….

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..

(Hand gesture)

B: No, and you get the satisfaction you've made something yourself and you didn't get it take out from MacDonald or something.



(Image processed for purposes of anonymity.)

Fig. 1 The annotated transcript of the SRC team's discussion

In their implicit understanding, however, the SRC team seemed to care for the users and not completely deny their responsibility to users. In their conversation, the SRC team kept addressing customers as "*you*," not as customers or users. Most SDP teams that participated in this study addressed users of their design product as "customers" or "users" during the discussion. When members of SDP teams said "*you*" during their conversation, they were usually addressing their team members or fellow engineers. Unlike other teams, the SRC team conversed as if they were engaged in a friendly talk with the users. For example, when student A said "it's your fault" to student D, it was said in a friendly teasing tone, and all the team members burst into laugh. At that moment, student D took a position of a disappointed user, and student A was not blaming a user but teasing her. When they say "you get satisfaction" or "you keep trying," the overall conversation sounded like a conversation between two users, one was giving an advice to the other. This choice of words can be compared to the team's choice of addressing recipe providers who would be the team's future business partners. The SRC team addressed recipe providers as "whoever" or "they" and never addressed them as "*you*" during the discussion. Also, when the SRC team brought up the question of "is it ethical that really, really looking good food there and have all the recipes and then sell some crappy food?" the team member showed hand gestures of offering something to someone (see Fig. 1). Then he gestured to write a list of something when he said "all the recipes." These gestures indicated that they were considering their design product as something they will offer to users, which means that they have full responsibility. Considering the choice of words and the hand gestures, the team seemed to care about the customers, at least more than recipe providers who can be their business partners. We explained the SRC team's detailed implicit understanding in our previous study (Lee et al. 2015). Table 6 shows the SRC team's explicit understanding and implicit understanding about this issue.

Table 6 The SRC team's explicit and implicit understanding of an engineering ethics issue

Explicit understanding	Implicit understanding
The team denied responsibility for the indirect outcome of their design	The team cared for the users and tried to seek the solution
The team shifted responsibility to the recipe providers	The team emotionally sided with them, not with the possible business partners

Table 7 The systematic problem-solving process analysis of the SRC team discussion

(Underlined: ethically salient words, *Italics: key words related to the project*, Shade: words addressing users, **Bold: non-verbal)**	
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)** **(Hand gestures of offering something)** **(Hand gestures of writing a list)**	*Describing the problem: "Is it ethical for us to sell the food when there is a discrepancy between the food & the picture?"
B: we're not selling crappy *food*, we're just selling according to how good a *cook* you are… C: yeah	*Analyzing the problem (Re-defining the problem): i) It is not engineers' problem. ii) Discrepancy depends on user's cooking skill. iii) The re-defined problem is how to improve users' cooking skill.
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	*Constructing the solution: i) Practice will improve users' cooking skill.
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.. **(Hand gesture)**	*Assessing the solution (in different criteria): i) In users' criterion, improving cooking skill is a solution. ii) In manufacturers' criterion, discrepancy depends on the recipe providers. iii) It is not engineers' problem
B: No, and you get the satisfaction you've made something yourself and you didn't get it take out from MacDonald or something.	*Exploiting the solution: i) Users can have an additional benefit of "Do it Yourself" experience.

The SRC team also conducted their discussion following Reif's systematic problem-solving process (see Table 7). What Reif terms their "final decision" reflected their explicit understanding, as in the case of the SSE team. Their implicit understanding, however, seemed to influence their discussion and decision-making process. Throughout the discussion, the team tried to find a solution for the potential users rather than simply blame them. It seems that the empathy that the team felt toward the users influenced the direction of the discussion. In the process of analyzing the problem, the team redefined the problem in terms of the users' perspective. So the problem of "Is it ethical that really looking good food and have all the recipes and then sell some crappy food?" was redefined to be the problem of how well a user can cook. Naturally, the solution they sought in the next phase was for the users, saying "but then eventually, if you keep trying, it will eventually look even better."

Discussion

Two findings from our study require a thorough discussion. First, there was a discrepancy between implicit and explicit understanding in both teams, and second, the teams demonstrated broader *implicit* than *explicit* understanding of the ethical and social implications of engineering. The discrepancy between implicit and explicit understanding seemed to create discord in the teams' problem-solving process. Although both teams arrived at conclusions that reflected their explicit understanding, the teams' implicit understanding played an important role during the discussion. What we think varied between the two teams is how their implicit understanding influenced the discussion.

In the SSE team's discussion, the team initially suggested a solution that reflected their implicit understanding, and they tried to come up with reasons to support this solution. This process was similar to how intuitive ethics works in moral judgment according to Haidt (2001; Haidt and Joseph 2004). According to Haidt, an intuitive judgment about an ethical issue is made first, followed by reasoning to provide post hoc support for that judgment. Based on this similarity, the SSE team's implicit understanding seemed to play a role of *intuitive ethics* in their ethics discussion. Their implicit understanding that immediately disapproved a high sale price issue may have a root in their intuition about fairness. According to Haidt, reasoning does not, typically, generate or alter judgments. In the SSE team's case, however, this intuitive judgment was not merely backed up by the teams' reasoning as Haidt would lead us to expect. Instead, the team's reasoning overrode the intuitive judgment and eventually led to the conclusion that represents the team's explicit understanding, that is, that their ethical responsibilities in this case are narrower than they had intuitively identified them.

The influence of implicit understanding seemed to be strong at the beginning of the discussion, but it gradually decreased. In fact, there was a distinct turning point when implicit understanding lost its influence (see Fig. 2). At this time, the team brought the example of the iPhone, which, like their design, is a luxury consumer good, not a matter of life and death. They also began to consider the broad social implications by mentioning all the involved parties, users' free will, and users' needs. It seems that the team simply think that there are some areas, such as medicine, in which the ethics issues are definitely right or wrong, whereas in the case of consumer goods like toys, there is no definitive answer to the ethical question they had raised. In terms of their explicit understanding of ethics, the possibility of moral disagreement on the matter undermined their ability to regard the matter seriously. This may be a result of their education and professionalization process in engineering, which is highly focused on technical skills and competencies, but provides little or no professional vocabulary or professional modes of reasoning about uncertain ethical issues. This may be why, e.g., the SSE team quickly moves from the fact of disagreement about the ethical concerns at hand, to

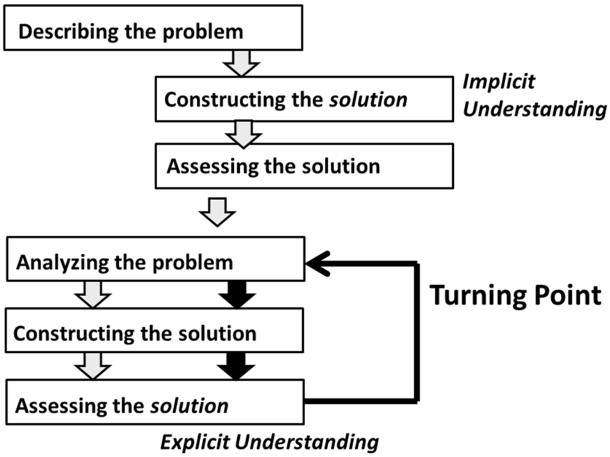


Fig. 2 The structure of the problem-solving process in the SSE team's discussion

the lack of a fact of the matter about the ethical evaluation, to dismissal of the problem that had been raised. The students' professional vocabulary and norms allows no possibility of taking issues seriously that lack clear, formal answers. Rather than acting as post hoc rationalization of their intuitive judgment, their reasoning process acted to decrease the breadth of responsibility the team was willing to assume.

Meanwhile, the SRC team's implicit understanding instead played the role of *ethical insight*, guiding the direction of their discussion (Roeser 2012). This team showed empathy for the users, which made them implicitly recognize their social responsibility for the design product. Their emotion seemed to become the source of their ethical insight. Although the team's discussion was systematically conducted, this ethical insight guided the discussion at every phase of the systematic problem-solving process (see Fig. 3). For example, the team redefined the problem from the users' perspective and found the solution for users. Further, they suggested that, even if they do not end up cooking good quality food, the users can have a "do it yourself" experience which can be enjoyable and beneficial.

Nevertheless, the influence of the ethical insight seems weak, due to the tension between their implicit and explicit understanding. Although the team's implicit understanding influenced the whole process of the discussion as ethical insight guides the direction of judgment, it was the team's explicit understanding that determined the direction of the decision-making. When the team assessed the constructed solution, they assessed the solution from two different perspectives. When taking users' perspectives, they accepted that practicing cooking skill could be a solution. However, when the team took engineers' perspectives, they changed the direction of the discussion, and decided that it was not the engineers' problem. Then the team denied their responsibility and shifted it to the recipe providers. Eventually, the team did not make any effort to change their design during the discussion.

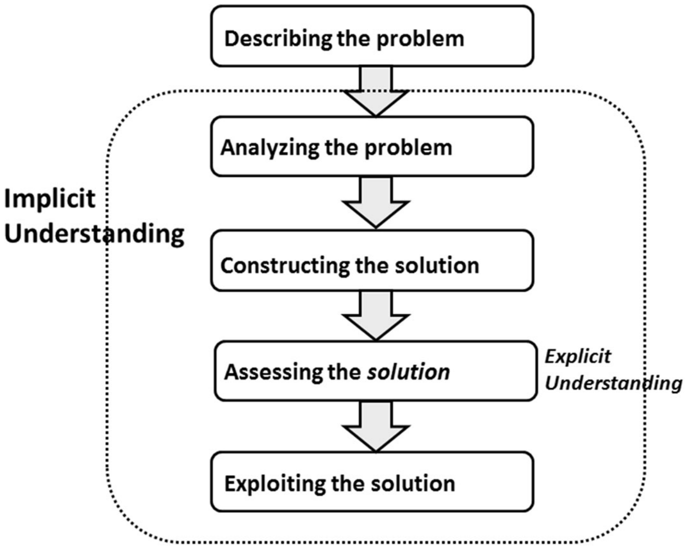


Fig. 3 The structure of the problem-solving process in the SRC team's discussion

As stated above, we adopted the approach of *situated* and *distributed cognition* in this study (Lave 1988; Lave and Wenger 1991; Hutchins 1995), and we considered student teams' ethics discussion as a socially situated activity. In our previous study, we found that engineering student teams have implicit understanding of engineering ethics (Lee et al. 2015), and in this study, we focused on how the student team's implicit understanding of engineering ethics influences the team's decision-making in a "real-life" situation, i.e., the situation of their actual design project. Engineering student teams' implicit understandings varied and there seemed to be various sources of these implicit understandings. As we observed in the SSE and the SRC team's cases, engineering student teams' implicit understandings played various roles in their decision-making. We propose that in case of some teams, implicit understanding plays a certain role in decision-making, and that role may be related to the micro-culture of the team, the project that they are working on, the work environment, and other situations.

Although the role of implicit understanding is similar to how intuitive ethics and ethical insight works in an individual's decision-making, there was a difference in how the SSE and the SRC teams approached the decision-making process. Haidt (2001, 2007) suggested that reasoning rarely overrides intuition in the moral judgment, however, the SSE team changed their initial judgment that came from intuitive ethics by step-by-step reasoning during their ethical decision-making process. In this process, the SSE team followed the systematic problem-solving process. On the other hand, the SRC team relied more on reasoning by assessing their tentative solution than on ethical insight to make a decision in their ethics discussion, though their emotions and feelings toward users guided the direction of the discussion as an ethical insight. The SRC team also followed the systematic problem-solving process. In both cases, the teams' implicit understanding played an influencing role during the discussion, but it did not strongly influence the final decision-making. In this way, the teams' behavior seems to match the critics who think that intuitive or emotional responses are biased and untrustworthy, and favor explicit reasoning processes in ethical decision-making. However, it seems doubtful in these cases that the teams' explicit understandings are actually superior to their implicit understandings.

We noted that the SSE and the SRC teams' decisions were consistent with their explicit understanding of engineering ethics, and both teams followed the systematic problem-solving process that engineering students may have been trained and encouraged to practice through their education. We think that these results are suggestive of what happens in real-life engineering ethics decision-making. As a team and not as an individual, the engineering student team seems to make a decision based on their explicit understanding of engineering ethics when they face the situation that requires an ethical decision in the line of work, though the team has also implicit understanding that plays a role during the decision-making process. If the team's explicit understanding were more appropriate than their implicit understanding in that situation, it would be beneficial to the team. As we observed in the cases of SSE and the SRC teams, however, if the team's implicit understanding is more appropriate than their explicit understanding in terms of the social implication of engineering, it would not be beneficial. Thus engineering education may need to find a way to encourage student teams' relevant implicit understanding of engineering ethics and let it play a beneficial role in ethical decision-making, or reform their explicit decision-making processes to prevent narrowing the sense of and disengagement from responsibilities.

Conclusion

The student teams' implicit understanding of engineering ethics seems to influence their decision-making process during an ethics discussion. Implicit understanding plays different roles during ethics discussions and decision-making, and we identified two such roles in this study: *intuitive ethics* and *ethical insight*. The influence of implicit understanding, however, seems to be weak compared to the influence of explicit understanding when the two are in tension, at least when it comes to engineering students navigating potential ethical problems. Thus the conclusion of the discussion always reflects a given team's explicit understanding.

In terms of engineering ethics education, we suggest that the students' implicit understanding can be a structuring resource for the process of ethical decision-making (Lave 1988), because their implicit understanding can play a role that contributes to shape the process of ethical decision-making. Therefore, if students have the relevant implicit understanding of engineering ethics as shown in this study, that implicit understanding should be encouraged to influence their decision-making or problem-solving process. To educate socially responsible future engineers, engineering education needs to pay attention to students' implicit understanding of engineering ethics and the role it plays in their decision-making process when engaging in engineering activities.

Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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