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Understanding the Communicative and Social Processes of Engineering Ethics in Diverse Design Teams

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Introduction

As engineering, and specifically engineering design, is increasingly understood to be a social activity, engineering education's understanding of ethics needs to reflect this developing awareness. Within engineering and design teams, engineering educators are concerned not only with how individual students develop ethically, but also how everyday ethical decision-making emerges during team interactions and becomes integrated in design solutions. Furthermore, these ethical decisions often do not present themselves as traditional dilemmas, but are issues that are confronted in the everyday process of design, and are influenced by team members' cultural and disciplinary backgrounds and the ethical climates of the team and the organization.

In considering engineering ethics education in this context, we can draw from the extensive scholarship on group communication. This body of literature suggests that team member interactions and communication have a major impact on a team's decision-making abilities, as well as the information that is discussed during the problem-solving process¹⁻⁴. Therefore, this project seeks to understand how everyday ethical decision-making is embedded in the processes and interactions of diverse engineering design team and their recognition of the long-term design consequences of their solutions and it guided by the following four research questions:

RQ1: How is "everyday ethics" experience and communicatively constituted by students in multidisciplinary engineering design teams?

RQ2: How do individual team members influence the team's organization and behaviors regarding ethics in team decision-making? How do the disciplinary diversity and cultural influences shape team member interactions in ethical decision-making?

RQ3: How do team organization and team member interactions shape team ethical decision-making behaviors and team ethical climate?

RQ4: What characteristics of team member interactions and team organizational structure can encourage teams in the development of ethical decision-making processes in multidisciplinary engineering design teams?

To answer our research questions, this study combines social network analysis (SNA) with structuration theory to examine the structure of project teams while also examining the institutional and contextual factors that contribute to team climate, and to the development of group norms that affect team interactions. SNA is a type of analysis that enables researchers to examine the relationships among members of a given system or group. In contrast to the "organizational chart" that might show how communication is *supposed* to flow within the organization, network analysis shows the *actual* communication and relationships that emerge within the organization or team. Structuration accounts for the influence of institutional factors such as rules or norms of what is "acceptable" or "appropriate" behavior within a specific social context, while also affording the actors within that context agency to influence those institutional factors. Primary data sources include a series of interviews and videotaped participatory

observations, as well as the social network analysis survey. In the paper, we describe the study frameworks and the specific methods employed in the project to date.

Motivation

This project builds upon prior NSF-funded projects that examined individual ethical decision-making and ethical team climate in multidisciplinary project teams in an engineering context. Our efforts centered on the development of two instruments, one to assess individual engineering ethical reasoning, and the other to assess team ethical climate. As part of the prior project, we conducted 51 interviews with students on these teams to probe the concepts examined in these instruments with the intent of qualitatively validating these instruments and providing greater depth and context⁵. In our analysis of these interviews, we uncovered consistent themes indicating that students did not identify issues such as a breach of a non-disclosure or confidentiality agreements or of overtly unsafe design elements as having ethical implications or decision making unless explicitly directed to frame such issues as ethical. In addition, students were not aware that they were engaged in smaller decisions that have ethical implications such as tensions among efficiencies or compliance with engineering standards, nor that they participated in ongoing ethical decision making during their interactions with each other and with their project partners or clients. Furthermore, they often did not consider how the context in which their design was being developed and for whom they were designing included ethical considerations.

Although students may realize neither that they are engaging in ethical processes nor how the context in which they work shapes and is shaped by their decisions, we take as a starting point that teams and individuals are engaged in ethical deliberations on an ongoing basis throughout the everyday engineering design process. Our project seeks to understand how such interactive processes occur in terms of the specific network structures and contexts of engineering projects within particular institutional programs; our project can inform best practices for engineering education to translate ongoing ethical decision-making processes into practice⁶⁻⁹. The following sections describe the frameworks from ethics, design, and communication that inform our study.

Kohlberg's Moral Development Theory

Kohlberg's moral development theory (and Neo-Kohlbergian revisions)¹⁰⁻¹¹ have been widely used to understand and assess moral reasoning in a variety of professional fields (e.g., science, engineering, medicine, and business) across cultures. From the perspective of moral cognition, *Kohlberg's theory attempts to understand how people reason morally and on what values their reasoning processes are based.*

Neo-Kohlbergian scholars divide moral development into three schemas. The first schema, *preconventional*, is concerned with a predominantly self-interested orientation. The second schema, *conventional*, is based on concerns for external factors (other people and authoritative rules/orders). The third schema, *postconventional*, builds ethical reasoning on universal norms and values (e.g., justice, human rights) that are *concerned with* and *good for everyone* in the world. Moral values and principles are not unquestionably accepted but subject to critique and reflection. Those who reason at this level have the highest level of moral development compared to people at the two earlier levels. Although individual ethical reasoning is necessary but not

sufficient for moral behavior in team contexts, a neo-Kohlbergian approach does help build the foundation for understanding the ethics in team communication and interactions and is a fundamental way of understanding the (ethical and cultural) diversity of team climate and structure.

Furthermore, postconventional thinking views ethical reasoning as a process based on social arrangements. Applied to the team contexts, “if social arrangements meet certain procedural norms the resulting decisions are considered acceptable”¹² (p. 104). These norms enable members to maintain ethical interactions in team structures and factor into everyday ethics.

Everyday Ethics

Scholarship in science and technology studies (STS) has shown that engineering design is a context in which ethical issues arise on a *day-to-day* basis or in what is called “everyday context”¹³. In engineering design, a “usual” impression is that not much engineering designing contains what is normally called “ethical dilemmas” in ethics classes and textbooks. For engineering designers, it is often the case that when looking back, “after things turned out nasty”, reasoning originally unrelated to ethics then turns out to be ethical reasoning after all¹⁴ (p. 514). On the whole engineering design might not seem to be specifically about what we would traditionally consider to be “ethical issues,” even though the *products* of an engineering design process, and especially the use of those products, undoubtedly is¹⁴ and any agreement achieved or decision made in the design process may result in potential social and ethical impacts.

In this sense, traditional engineering ethics has been criticized by STS scholars as “an externalist approach” to technology where ethics is an external force acting upon design or a “check list” that focuses on “the outcomes of processes of technology development rather than on the *internal dynamic* of these processes”¹³ (p. 224, emphasis added). STS scholars advocate an *internalist* approach that attempts to open the “black box” of technology to complement a traditional externalist approach to engineering ethics. Ethical reflection during the design process requires anticipation of the future role of technologies-in-design in their use context¹⁵, where ethics is an indispensable component that is possible to be combined with other technical components in design. Besides avoiding doing harm and preventing negative effects of technology emphasized by traditional “preventative/passive ethics”, the everyday ethics approach also focuses on active responsibility of the effects of technology.

Design Context

Design has been characterized by many different “design process” models¹⁶⁻²⁰ and definitions²¹⁻²³. The many design definitions and processes reflect different design approaches, philosophies, and values. For example, technology-centered design has been defined as a process in which the designers or their clients make design decisions which are imposed on the intended users²⁴⁻²⁵, whereas human-centered design have human beings as central in the process, involve users throughout the design process, and seek to understand them holistically²⁶. In the context of design, there are many different values, such as innovation or a primary concern for safety, that guide design decisions and processes, and can impact how designers think about the ethical issues related to their designs and the implications of their “everyday” ethical decisions. A human-centered approach is an example of a design value that would be intertwined with the

design process. For example, in their phenomenographic study of human-centered design, Zoltowski, Oakes, and Cardella²⁷ identified seven distinct ways that students experience (and understand) human-centered design. The most comprehensive category from this study, Empathic Design, was characterized by a very broad and integrated understanding of the stakeholders and the social, cultural, political, technical, and ethical issues associated with the design. Design knowledge was gained through a connection with end users and there was evidence of their consideration of “everyday ethics” throughout their design process.

Ethics in Team Communication and Interactions

Group communication scholars have extensively examined decision-making processes in teams, finding how team characteristics such as diversity and status differences affect team decision-making and performance. Individual team members can significantly affect the team’s performance, the way members relate to one another, the type of information that is shared and discussed, and a number of other factors that contribute significantly to a team’s functioning and decision-making²⁸⁻³². This effect is even more pronounced for smaller teams of people³³, such as project teams. The team’s diversity can influence decision-making and performance. Researchers have found that diversity among team members has several implications. First, more diversity in terms of age and educational experience have been linked positively to team performance³⁴. Additionally, overall, more diverse work groups often produce more flexibility, innovation, and productivity³⁵⁻³⁶. However, research also has indicated that these more diverse work groups often encounter difficulty initially in terms of group performance and functioning³⁵.

Cultural diversity also impacts a team’s interactions and decision-making processes, providing both benefits and challenges. Some obvious challenges include potential language barriers, but nonverbal cultural differences can also make team interactions more difficult. Cultural diversity can offer more opinions and perspectives on problems³⁶⁻³⁷, and could influence the team to take into consideration a wider view of the end user of the product or its functionalities. Culture can also impact the development of team norms, the quality of discussion and inclusivity of team members, and the clarity of the decision-making process.

Team Network Structure and Ethical Interactions

In understanding decision-making and ethical reasoning in teams, the role of communication becomes essential in the team context. Communication encompasses the verbal messages team members use to share information with each other, but also involves nonverbal factors (such as “body language” and seeming enthusiastic or skeptical), and the relations formed between members as they interact. Several studies have found that the way team members communicate with each other is crucial in determining how they collaborate and the success of those efforts³⁸⁻⁴⁰. However, the precise role of communication in contributing to a group’s success is still a matter of debate⁴¹, with calls for more extensive work analyzing these effects⁴.

Past research has examined ethical behavior in organizations noting its highly complex nature and many influences. For instance, scholars in organizational studies have debated about the root of unethical decision-making and behaviors, arguing whether it is a function of “bad apples” or “bad barrels”⁴², that is, whether individual characteristics or organizational and societal influences are greater contributors. More complex models have been developed to describe a

complex interaction between these factors, such as a focus on the types of ethical issues and their “moral intensity” in determining ethical responses⁴³. The importance of relationships among social actors in an organization or team has emerged as an essential consideration in this debate⁴⁴. However, these studies have failed to examine the decision-making process itself, focusing rather on the outcomes and net effect of these interactions.

Social Network Analysis

As indicated earlier, social network analysis (SNA) is a type of analysis that enables researchers to examine the relationships among members of a given system or group. Several elements of social network analysis are important in understanding the strength, linkages, and patterns of team networks: external structural rules (or network-level measurements) of network density; the presence of weak ties; and internal structural rules (or those that give information about the participation of each specific actor in the network) including degree centrality and individual ethical attributes. Different network structures have been found to affect employability, employee turnover, employee satisfaction, and creativity⁴⁶⁻⁴⁷. However, how such elements of team network structures affect team ethical decision making is not known. Indeed, Whitbred et al.⁹ recommend that “Future research should focus on establishing whether the structuration of social networks will vary depending on the nature of the organization and, if so, which structural rules would emerge as being most important in these other contexts” (p. 425) particularly for engineering design teams.

Structuration Theory

This study follows Whitbred et al.⁹'s approach that combines social network analysis with structuration theory. This approach enables us to examine the structure of project teams while also examining the institutional and contextual factors that contribute to team climate, and to the development of group norms that affect team interactions. Structuration accounts for the influence of institutional factors such as rules or norms of what is “acceptable” or “appropriate” behavior within a specific social context, while also affording the actors within that context agency to effect those structural influences. This theory envisions a reflexive relationship in which institutional influences constrain and enable individual activity, while individual activity reinforces these structures and shapes them over time. Network analysis provides a concrete visualization of this relationship, showing the relational patterns of individuals to both identify local structural properties and utilize these properties to help predict and explain changes in the network structure⁹.

Research Design

Our study, guided by the four research questions stated earlier, contributes to our understanding of “everyday ethics” and ethical decision-making in project teams by looking at what happens *in practice* during engineering design, in an undergraduate context, and with explicit attention paid to the team communicative process. The expected outcomes are as follows:

1. Findings on how "everyday" ethics is communicatively constituted in the engineering design team processes.

2. Findings on how individual team members influence the team's organization and behaviors in team decision-making, and how those are influenced by disciplinary and cultural diversity.
3. Findings on how team ethical decision-making is shaped by the organization of the team and the interactions of the team members.
4. Findings on what characteristics of the team structure and interactions facilitate the ethical decision-making processes of the students as well as contribute to their ability to make ethical design decisions within their project teams.

The model in Figure 1 illustrates the reflexive relationship between individual and team ethical reasoning, and how network structure and interactions both complicate and shape these decision-making processes. Furthermore, it demonstrates the influence of the design and institutional contexts, as well as individual and team factors and characteristics.

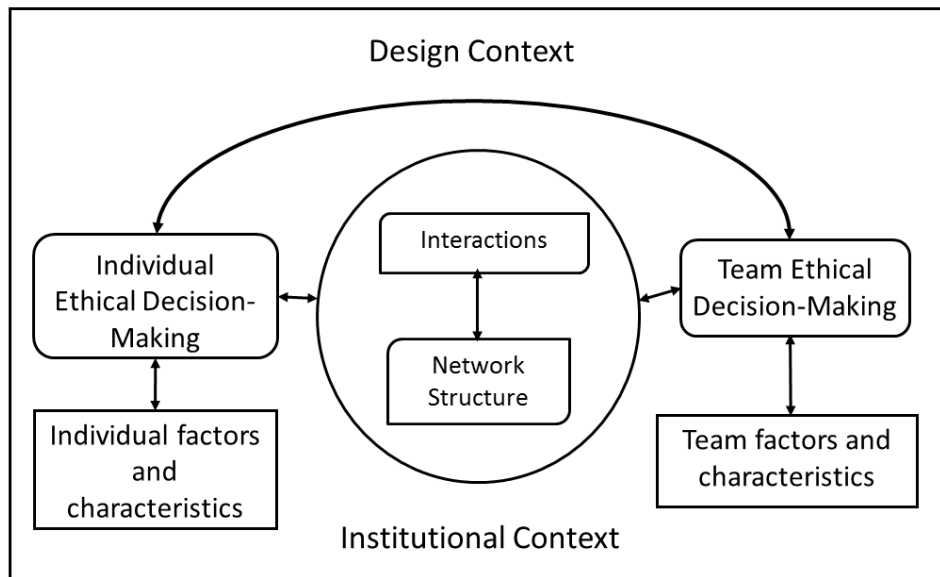


Figure 1. Relationship between different components

Methods

This study employs a mixed methodological approach⁴⁸⁻⁴⁹ in order to gain a comprehensive understanding of the issues raised above, with emphasis on a qualitative approach to the study of project teams. Combining multiple and complementary data sources and paradigms provide “strengths that offset the weaknesses of both quantitative and qualitative research⁴⁸” (p. 12). This study utilizes a convergent (quan/QUAL) parallel design⁴⁸. The qualitative data sources that include in-depth semi-structured interviews and videotaped participatory observations will let us explore how team members perceive, experience and understand ethics (the “everyday ethics”) of design; while the Social Network Analysis (SNA) component of the study will let us explore team structural characteristics and their impact on those perceptions and the team’s overall discussions and decision-making.

Participants and Recruitment Strategies

We have purposefully selected four diverse project teams within the EPICS program, a service-learning design program at Purdue University. In this program, teams of undergraduates partner with local or global not-for-profit community organizations to define, design, build, test, deploy, and support engineering-centered projects that significantly improve the organization's ability to serve the community. There are larger teams that represent the class division that generally have the same project partner, as well as project teams that share a common design goal. Students can participate multiple semesters; teams typically have a mix of returning and new students. Students take on different roles, such as project manager, design lead, financial officer, and project partner liaison. To maximize the use of social network analysis, we selected four project teams within four separate classes comprised of 2-6 project teams each to follow each semester that consist of 70-80 individuals total, including instructors (advisors) and graduate teaching assistants. This format enables us to examine relations within the specific project teams, as well as how project teams interact with others in the same class. Project teams ranged from 3-9 members. We purposefully sampled project teams that are culturally diverse as well as those which are multidisciplinary. We are conducting data collection at the end of two consecutive semesters. During the second semester, we are purposefully sampling a limited number of teams with various levels of membership change from the first semester so that we can examine how the team structure and interactions change as team membership changes.

Observations

To enable analysis of the interactions of the team members during their decision-making discussions, we observed several meetings (designated class period, outside project meetings) of the selected project teams. We are following the guidelines for conducting naturalistic study⁵⁰, observing the practical accomplishments of everyday meetings to understand how the team communicatively constitutes ethics in the decision-making process. To allow for rich analysis of these interactions as well as repeated viewing of the interactions as they happen, we will also use video recording to capture these interactions.

Research memos of the observations are completed and will be used to provide insight into how team members negotiate value differences or conflicts, what role members seemed to occupy during these discussions, what issues were raised and how the team treated these issues, and other relevant interactions that emerge from this examination. We will examine the flow of interaction among participants and how what they say and do maintains or alters the ethical decision making.

Social Network Analysis

The social network analysis⁵¹ (SNA) was administered to all members of the four classes, allowing us to assess a large network (the class) and how the project teams within it interact. The survey contained two sections: (a) a sociometric instrument that provides a complete list of all the members of a project team and asks the participant to relate their communicative relationships with them⁵¹, and (b) relevant demographic information including age, gender, ethnic/race category, perceived role in the group, and other important factors that may be considered at various points in the analysis. Although data collection occurs once per semester,

the interview and survey asks participants to discuss how the interactions have changed over the course of the semester.

Using *UCINET*, a social network analysis tool, we are examining two levels of social network measurements, those that describe the network as a whole (network density and the presence of weak ties) and those that give information about the participation of each specific actor in the network (degree centrality and individual ethical attributes). These analyses illustrate whether certain individuals in the project teams have more influence in specific relational contexts. These results will be examined to identify correlations between certain network or actor measurements and the emergent network structure these qualities produce. These results will be examined with and in comparison to the results of the qualitative data analysis and in light of the theoretical framework of this study to identify implications of their relationships.

Moral Reasoning as Individual Attributes

In addition to traditional network measurements, we are utilizing the scores from our measure of individual ethical reasoning instrument⁵² of individuals to visualize the “ethical network” structure that emerges within the project teams during the second data collection. By treating an individual’s score as an attribute, we will be able to run analyses to examine the relationships and structures that emerge among team members according to this attribute--for example, do high moral reasoning individuals operating at a post-conventional level cluster together? Do they frequently emerge as central in the network, or have positions of particular prominence or influence? We will be able to examine whether an individual’s influence extends to ethical decision making such that team climates, and the discussions surrounding decision-making on the team, reflect their positions.

Interviews

To date we have conducted 66 in-depth interviews that probe deeply into the team and design process. There are two sections to the interviews. The first is a semi-structured interview with questions about team member interactions, design decisions, and considerations the participant had as well as any considerations that were raised by other team members. These questions were adapted from the interview protocol used in our previous project and follow these themes:

- asking participants to recall and describe two or three decisions their team has made thus far in the project
- asking them to describe as they see it the design process their team has followed, including asking them to chart out the choices the team has made along a timeline
- asking about team member interactions, such as who the participant would go to for advice, who speaks up most often in team discussions, what is the tone and atmosphere of decision-making discussions, and how the participant perceives the roles and qualifications of each member of their project team

The second part of the interview explores the participants’ responses to the SNA survey, probing why they indicated the people they did and differences in responses to the categories. Interviews are being transcribed and de-identified to protect participants’ identities. We have begun analysis of the interview data using a typological analysis approach⁵³⁻⁵⁴. Initial codes were generated from the individual ethical reasoning and team culture instruments we are developing.

As we analyze this interview data, any themes or ideas that seem prevalent across respondents are being added. We are comparing and contrasting findings emerging from data with interdisciplinary research to uncover regular patterns of communication that indicate how ethics is communicatively constituted by team members, team norms for ethical decision making procedures, and other aspects that are part of team processes.

Future Work

We are conducting our second round of data collection this semester (Spring 2015), following the same four project teams that were observed, interviewed, and completed the social analysis network (SNA) survey during the Fall, 2014 semester. A third data collection is planned for Fall, 2015. Data analyses and integration of the interviews, SNA surveys, and observation are ongoing.

Summary

This study builds on prior NSF-funded work and a broad literature from engineering education and the social sciences to address the compelling issue of ethical awareness and ethical reasoning within diverse design teams. Design is a central function of engineering and ethics is often learned within undergraduate design courses where many ethical decisions are made through smaller more frequent design decisions and involve interactions with team members. This project fills a gap in ethics scholarship by examining how everyday ethical decision-making is integrated systematically in the design processes and interactions of diverse design teams. It examines ongoing ethical decision-making interactions and structures that occur during the everyday work of diverse design teams and lays the foundation to create models that can inform curriculum development.

The findings of this research have potential impacts across engineering education. Today's technology provides the engineering community with an enormous opportunity to positively impact society if applied appropriately. Today's global society adds complexity to the social and ethical issues that need to be addressed by designers and professionals as technology is applied to address needs. Better understanding the development of ethical reasoning within diverse design teams as they make design decisions can greatly enhance the way engineers and other technical professionals learn key attributes called for by ABET, the NAE's *Engineer of 2020*, and industry stakeholders. Designing curricular experiences to equip engineering students to address ethical and societal challenges requires developmental ethical models that account for team interactions as they produce or constitute the nature, meaning, and outcomes of ethical decision making, structures that emerge as design teams operate and that shape and are shaped by ethical decision-making behaviors, and how these interactions and structures are influenced by different disciplines, cultures, and organizational climates. The project also introduces cross-disciplinary research methods from communication into engineering education.

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