Applying Critical Incident Technique to Investigate Changes in Ways of Experiencing Ethical Engineering Practice

Ms. Dayoung Kim, Purdue University-Main Campus, West Lafayette (College of Engineering)

Dayoung Kim is a Ph.D. student in the School of Engineering Education at Purdue University. Her current research interest centers on engineering ethics and social responsibility, and she is specifically interested in cultural influences on engineers' moral formation. She earned her B.S. degree in Chemical Engineering at Yonsei University, South Korea in 2017.

Dr. Justin L Hess, Purdue University at West Lafayette

Dr. Justin L Hess is an assistant professor in the School of Engineering Education at Purdue University. Dr. Hess's research interests include exploring empathy's functional role in engineering; advancing the state of the art of engineering ethics instruction; and evaluating learning in the spaces of design, ethics, and sustainability. Justin received his PhD from Purdue University's School of Engineering Education, as well as a Master of Science and Bachelor of Science from Purdue University's School of Civil Engineering. Justin is the 2020 program chair for the ASEE LEES division.

Dr. Nicholas D. Fila, Iowa State University

Nicholas D. Fila is an assistant research professor in the Department of Electrical and Computer Engineering at Iowa State University. He earned a B.S. in Electrical Engineering and a M.S. in Electrical and Computer Engineering from the University of Illinois at Urbana-Champaign and a Ph.D. in Engineering Education from Purdue University. His current research explores engineering students' experiences with innovation, empathy across engineering education and engineering design settings, design thinking in the course design process, and novel uses of qualitative research methods in engineering education.

Applying Critical Incident Technique to Identify Changes in Ways of Experiencing Ethical Engineering Practice

Abstract

This study applied Critical Incident Technique (CIT) to identify potential causes of changes in ways of experiencing ethical engineering practice in the health products industry. We use the term *change* broadly to refer to any shift, refinement, or reaffirmation in one's way of experiencing. We applied CIT to study 25 interviews with engineering practitioners from health product industry across three industry sectors: orthopedics, pharmaceuticals, and medical devices. CIT analysis began with one researcher identifying potentially critical incidents while guided by three criteria. Next, two other researchers reviewed each potential incident, which led to the identification of 81 incidents across the interviews. After review and finalization of incidents, we utilized an inductive and iterative thematic analysis process to identify distinct types of incidents. Critical incidents have been sorted into 25 themes and seven categories which represented potential causes of changes in ways of experiencing engineering ethics in the health products industry. Categories included: (1) Cultural Immersion, (2) Acting Ethically, (3) Ethical Failures, (4) Interpersonal Encounters, (5) Mentorship and Management, (6) Reflection and Association, and (7) Prior Ethics Training. These findings suggest the importance of workplace culture in changing or solidifying individuals' ways of experiencing ethical practice. These findings can inform post-secondary engineering ethics instruction as well as workplace training.

Background

Since ABET EC 2000, interest in and emphasis on engineering ethics education has proliferated. Educators have invented and applied various training methods in engineering classrooms, including utilizing engineering professional codes of ethics and case studies. Engineering educators have reported on the effectiveness of such educational interventions [1] and discussed potential best practices [2], but the extent to which current engineering ethics education aligns with actual professional practice remains largely unknown. As a result, some scholars have criticized current approaches in engineering ethics education. These critiques demonstrate a concern among scholars regarding the extent to which post-secondary ethics education prepares engineering students for ethical engineering practice [3]–[5].

Our NSF-funded research project intends to address that concern by first exploring the various ways that engineers experience ethics in practice and then analyzing what influences that variation in experiences [6], [7]. In the first phase of the project, we utilized phenomenography to develop a comprehensive framework, grounded in the lived experiences of engineers, that describes variation in ways of experiencing engineering ethics. This study pertains to the project's second phase, wherein **our objective is to identify factors that potentially influenced changes in ways of experiencing ethics**. Hence, while the first phase focused on ways of experiencing ethics, this second phase focuses on **changes** in ways of experiencing ethics. We

use the term *change* broadly to refer to any shift, refinement, or reaffirmation in one's understanding of ethical engineering practice.

We hope that by exploring changes in how practicing engineers experience ethics throughout their careers, including how and to what extent myriad aspects of the work environment influence one's way of experiencing ethics, we will be positioned to identity which teaching approaches are best aligned with how ethics learning actually occurs in engineering settings and whether new pedagogy or interventions are needed. We do not anticipate the findings about change incidents and influences to necessarily be normative (i.e., we do not assume the change in engineers' ways of experiencing ethics always occur in a *desirable* direction). However, we do anticipate gaining deeper insights into ways that engineers may be influenced.

The following research question guides this study: "What aspects of the engineering practitioners' experiences, in practice or life, potentially promote changes in their ways of experiencing ethics in engineering?"

Research Methods

Interview Protocol

The data source were semi-structured interviews that were approximately 90 minutes in length. Interviews thoroughly explored one or more discrete experiences related to engineering ethics, conceptualizations of engineering ethics, and summative questions based on those experiences and conceptualizations. Interviewees were all engineers working for one of three companies within the health products industry. Three separate interviewers, including authors Fila and Hess, led interviews for one respective company each, and author Kim joined in as many interviews as possible. Previously, we documented the process behind the design of the interview protocol [6] and the steps we utilized to ensure research quality [8].

Setting and Participants

A subset of participants (n = 25) from the phenomenographic study [6] were randomly selected for additional critical incident analysis. Post-hoc, we checked for variation in demographics (e.g., gender, degree, role) to ensure sufficient differences among the participants. Table 1 provides an overview of study participants' demographics. All names are pseudonyms. In the future, we intend to analyze all 43 interviews.

Table 1: Participant list with demographic breakdown of the initial 25 interviews included in this CIT analysis.

Pseudonym	Role	Industry/ Field	Years in Field	Yrs. Engr. Experience	Disc. of Highest Degree	Highest Degree	Gender	Race/ Ethnicity
Alisha	Quality assurance	Medical Devices	2	3	Biomedical	MS	Female	Asian
Angela	Product development	Medical Devices	13	18	Chemical	MS	Female	White
Asics	Research	Orthopedics	2	3	Biomedical	PhD	Male	White
Blank	Manufacturing	Pharmaceuticals	20	26	Industrial	MS	Male	White
Carl	Product development	Medical Devices	34	34	Electrical	MS	Male	White
Charlie	Product development	Orthopedics	2	2	Biomedical	MS	Female	Black
Chesterton	Distribution (Facilities Engineering)	Pharmaceuticals	3	29	Mechanical	MS	Male	White
Cooper	Manufacturing	Pharmaceuticals	3	6	Chemical	BS	Female	White
Cy	Product development	Orthopedics	3	4	Biomedical	BS	Male	White
Dick Butkus	Manufacturing, Product development	Orthopedics	10	10	Mechanical	BS	Male	White
Elizabeth	Product development, Quality assurance, Research, Regulatory	Medical Devices	23	23	Interdisciplinary, Multidisciplinary	MS	Female	White
Eric	Regulatory	Medical Devices	7	7	Biomedical	PhD	Male	Asian
Ferrari	Manufacturing	Pharmaceuticals	15	20	Mechanical	MS	Male	White
Henry	Manufacturing	Medical Devices	1	3	Mechanical Engr. Technology	BS	Male	White
Iowa	Manufacturing	Pharmaceuticals	7	7	Mechanical	BS	Female	Hispanic, White
Jake	Manufacturing	Medical Devices	2	3	Biomedical	BS	Male	White
James	Research	Medical Devices	6	10	Chemical	PhD	Male	Black
Johnny	Quality assurance	Orthopedics	4	5	Biomedical	MS	Male	White
Jordan	Manufacturing	Pharmaceuticals	2	14	Electrical	MS	Male	Black
Maya	Product development, Research	Pharmaceuticals	6	6	Mechanical	BS	Female	Asian, White
Rachel	Quality assurance	Orthopedics	4	4	Biomedical	MS	Female	Asian
Raider	Facilities/Projects	Pharmaceuticals	28	28	Electrical	BS	Male	White
Rich	Product development, Quality assurance	Orthopedics	0	1	Biomedical	Some College	Male	White
Sarah	Regulatory	Medical Devices	7	1	Biomedical	BS	Female	White
Walter	Product development, Research	Orthopedics	30	25	Mechanical	PhD	Male	White

Data Analysis

We utilized a four-step hybrid of critical incident technique [9], [10] paired with thematic analysis [11]. Step 1 of the analysis involved identifying potential incidents; Step 2 involved sorting of incidents into preliminary categories; Step 3 involved reviewing and critiquing categories; and Step 4 involved finalizing categories and developing their narratives. The following subsections provide a detailed description of each step.

Step 1: Identify potential incidents and ensure they meet criteria

We used Butterfield and colleagues' [10] suggestions when setting criteria for identifying and selecting critical incidents. Specifically, they indicated that critical incidents must include three aspects: (1) antecedent information, (2) a detailed description of the experience (incident), and (3) an outcome of the incident (p. 488). As we reviewed interview passages, we similarly sought three components:

(1) **Antecedent information**: Description or demonstration of interviewee's way of experiencing ethics in engineering. Direct connections to ethics were preferred, but this connection could be inferred from a participant's category of description (obtained from the phenomenographic study) or contextual cues in the interview and/or excerpt.
(2) **Detailed description:** Detailed description of an experience or series of experiences that were directly attributable to the aspect(s) of their way of experiencing ethics in engineering.
(3) **Outcome of the incident**: A clear change, refinement, or crystallization in one's view of ethics in engineering, especially pertaining to a participant's way of experiencing ethics in engineering.

Kim reviewed the selected 25 interviews and extracted potential critical incidents. Incidents varied in length from one to several paragraphs. In most cases a critical incident was extracted wholly from one part of the interview, but in some instances, passages later in the interview were paired with earlier interview text to complete an incident and to capture the entirety of the above criteria. After this initial step, 93 potential incidents were obtained for analysis. Fila and Hess reviewed all incidents as a check to ensure their alignment with the above criteria. Fila, Hess, and Kim met to discuss these reviews. As a result of this process, 11 incidents were removed, three incidents were combined with three other incidents, and three incidents were divided into multiple incidents. As a result of this process, 81 incidents remained for analysis (note, in subsequent steps, incidents might still be combined or divided based on further analyses).

Step 2: Sorting incidents and initial category development

The objective of Step 2 was to sort incidents into discrete themes and to begin describing the nature of those themes. Throughout Step 1, the authors were documenting the rationale behind the criticality of an incident. Hence, while Step 2 was led by Hess, the prior descriptions and notes facilitated the sorting in Step 2. Here, incidents were grouped with like-incidents, and the

potential causes were narrated. As novel incidents were grouped beside existing emergent themes, prior incidents within a group were revisited and the description of that theme was further explicated to ensure the description captured sentiments across all incidents. As thematic analysis continued and more themes emerged, existing themes were categorized alongside like-themes. This process was iterative, with themes remaining fluid across categories and incidents potentially moving across themes as further narration continued. This Step 2 closed with a preliminary category and thematic structure and all incidents sorted.

Step 3: Review and critique

Step 3 opened with Hess describing the categories and themes to Fila and Kim. Next, Fila and Kim each reviewed a separate half of the incidents and placed each incident into the theme that they felt it most closely aligned. Hence, Fila and Kim did a kind of deductive coding with Hess' initial categories and themes as a coding framework without relying on Hess' coding results. In instances where Fila and Kim felt that an incident did not fit within an existing theme, they suggested revisions to existing themes or proposed new themes. In total, there were 44 agreements, 21 instances where Fila and Kim positioned an incident in a category where Hess did not originally situate the incident (this includes positioning incidents in new themes), and 16 instances where Fila and Kim were not able to place an incident in the existing thematic structure. Fila, Hess, and Kim met to discuss all suggestions, paying most attention to disagreements or uncertain groupings.

Step 4: Finalization and narration

Step 4 opened with Fila seeking to incorporate suggestions from Step 3 to ensure themes accurately portrayed the critical essence of change. This process led to several more conversations between the authors. Finally, Hess utilized notes taken throughout the Steps 3 and 4 conversations to update the thematic structure one last time and to begin narrating the structure for external presentation. Notably, Hess marked 15 incidents for further review at this stage, which Fila and Kim further reviewed. In this way, all three authors were in complete agreement with the final placement of incidents and thematic descriptions.

Results

From the sorting and grouping of the 81 incidents, 25 themes have been identified to date which represented potential causes of changes in ways of experiencing engineering ethics in the health products industry. The results of our current analysis (i.e., 25 of 43 interviews) include seven initial categories: (1) Cultural Immersion, (2) Acting Ethically, (3) Ethical Failures, (4) Interpersonal Encounters, (5) Mentorship and Management, (6) Reflection and Association, and (7) Prior Ethics Training. Further, those seven categories could be classified into two types based on the characteristic of the constituting incidents – continuous (i.e., the criticality of the incident involved the cumulative effect of multiple experiences over time) and acute (i.e., the criticality manifested at a single point in time).

The first category, *Cultural Immersion,* mostly consisted of continuous incidents. The remaining six categories mostly consisted of acute incidents. The following sub-sections describe each category in more detail. The presentation of categories roughly follows the descending order of the number of incidents included in the category. In our presentation of each category, we describe one or two representative theme(s) to contextualize the findings.

Category 1: Cultural Immersion

Incidents in this category included five themes: (1) Workplace Culture, (2) Cumulative Experience, (3) Role Immersion, (4) Comparing and Contrasting Cultures, and (5) Value Conflict. This was our most saturated category, as it contained 34 of the 81 incidents from 18 of the 25 participants. Most of the incidents were continuous, lasting over long periods in time. Table 2 provides a brief description of each theme, including participants that experienced each incident type. The number in the parenthesis in the participants column represents the number of incidents from that participant coded under the same theme.

Table 2. Cultural Immersion Themes, Thematic Descriptions, and Participant Mapping

Theme	**Description**	**Participants**
Workplace Culture	Consistent reinforcement of core values and practices in an organization through two or more of the following: (1) continuity of messaging, (2) overt leadership behaviors, (3) seeing norms manifest during meetings, (4) co-worker interactions, (5) presence of cultural artifacts, or (6) workplace training.	Alisha, Blank (2), Cooper, Elizabeth, Eric, Ferrari, Henry (2), Jake, Maya, Sarah
Cumulative Experience	Cumulative effect of encounters with ethics within workplace culture. Isolated experiences are not change-inducing on their own but change-inducing when considering the multitude of similar and distinct experiences.	Blank, Dick, Elizabeth (2), Ferrari, Jordan, Raider
Role Immersion	Experiencing ethically-salient situations within an organizational role or unit. Change results from engaging with unique situations and activities and/or responsibilities of the role.	Dick, Eric, Jake (2), Maya, Rachel (3), Raider, Sarah
Comparing / Contrasting Cultures	Comparing and contrasting facets of culture (e.g., norms, practices, values) between: (1) distinct domains within company, (2) different companies in the health products industry, (3) the health products industry and other engineering cultures, or (4) the current and the past.	Elizabeth (2), Johnny, Raider
Value Conflict	Finding personal values are at odds with supervisors, company decision-makers, or broader company culture, and then grappling with questions of agency.	Charlie, Iowa

In a sense, this category challenged our initial preconceptions, as we had anticipated that critical incidents would be acute or single experiences. Here, however, the combined effect of myriad experiences was the defining characteristic generating potential changes in one's way of experiencing ethics. As Workplace Culture was the most represented theme in this category and as Blank had two experiences categorized here, we utilize Blank's incidents to illustrate.

In the first incident, Blank discussed myriad collective impacts that, taken together, solidified his way of experiencing ethics. In the first incident, he discussed the collective impact of (1) training around standard operating procedures (SOPs), (2) the reinforcement and follow-through of SOPs in all practices, (3) integrity as a core value that is "talked about all the time," and (4) annual training on ethics and integrity that reinforces core value and SOPs. In the second incident, Blank discussed the overall impact of (1) explicit ethics-related messaging by his CEO through email or via blog and which was sent at opportune times (i.e., before training, before a product launch, after a milestone), (2) reinforcement of messaging throughout different layers of company leadership (i.e., divisional leadership, site leadership), and (3) the overall accessibility of policies or expectations. As Blank stated in the latter incident:

> So, it's just ... It's CEO down to divisional leadership down to the site leadership. It's really strong. I think that's important. And then I think it's, secondary, it's then backed up with being written down. So, it's not gray. If we wanted to, I could go find all those policies and procedures and we can pull them up and we could read them, and I wouldn't have a hard time doing it, because I know where they're at.

Due to the continuous nature of incidents in this category, these themes overlapped with nearly every other category, as living within a culture presents myriad opportunities to act ethically, fail, engage with others, receive mentorship, offer mentorship, apply prior ethics learning, and reflect. However, unlike the following categories, in these incidents, the combined effect of experiences generated a change in a way of experiencing ethics. The change was likely more gradual here than in other categories, but the pervasiveness of incidents sorted here supports the importance of senior leadership and a workplace that reinforces ethics throughout all aspects of an engineer's practice.

Category 2: Acting Ethically

Incidents in this category found participants acting in a way that either they perceived as ethical, or where they grappled with ethics in a novel way. We grouped four themes to this category: (1) Acting Ethically Despite Potential Inconvenience, (2) Steadfastness, (3) Working through Uncertainty, and (4) Critically Questioning. Nine of the 25 participants had experiences grouped here, and 11 incidents total were grouped here. Table 3 provides a brief description of each theme, as well as the participants with incidents grouped to each theme.

Table 3. Acting Ethically Themes, Thematic Description, and Participant Mapping

Theme	Description	Participants
Acting Ethically Despite Potential Inconvenience	Overcoming any sort of internal turmoil to act in a way that one perceives as ethical but that may be potentially inconvenient from a company perspective, namely, due to timeline or financial concerns. Post-hoc, and to one's surprise, receiving support from colleagues or superiors.	Carla, Iowa, Maya
Steadfastness	Holding one's ground or staying the course with ethical actions, even when receiving pushback. Generally, these incidents were interpersonal and involved trying to get others in alignment with one's views of ethical actions	Dick, Rachel
Working through Uncertainty	Working through a novel and/or uncertain ethical challenge. Uncertainty regarding what the "right thing to do" may be due to one or multiple reasons (e.g., no procedure exists, one has never experienced it before, misalignment between moral compass and standard operation procedures).	Rachel (2), Rich, Sarah
Critically Questioning	Continually asking, "Why?" in order to personally establish a more comprehensive understanding of the rationale behind a decision and a sense of whether one is convinced of that decision's ethicality.	Cooper, Cy

As one example of the Acting Ethically Despite Potential Inconvenience theme, Maya described needing to halt the timeline on a device launch in the early stages of product development. Maya was working in a product development role but, based on her prior experiences in manufacturing, she feared management's response to learning of a delay to the schedule. However, Maya left the encounter feeling empowered, and more confident that management's values prioritized safety beyond Maya's preconception. As Maya described:

> We had to go to management to tell them that we failed and that we'll need more time and we'll definitely compromise the schedule from finding this. Kind of admitting that our initial design failed and that we need to go back to the drawing board and waste more time and money to get it right. And they're surprisingly on board in fixing it. […] I was surprised when they were okay with it. Because I was expecting them to be really upset that we didn't meet their expectations. But at the same time I realize now that I said it that I shouldn't be surprised because all the people that I'm surrounded by, even in management, have the same ideals that we need to make everything as best as we can with the patient in mind and that we need to hold the best integrity while we're doing it.

Incidents in this category often overlapped with other categories, especially *Cultural Immersion* and *Interpersonal Encounters*. For example, the Working through Uncertainty theme aligned with role immersion theme detailed in the cultural immersion category. Here, however, experiences were more concrete. There, experiences were multiple and tended to arise from

one's immersion in a new role. Hence, the essence of the criticality seems to shift based on the conditions surrounding the ethical encounter and the temporal nature of the encounter.

Category 3: Ethical Failures

This category provides a descriptive counterpoint to follow *Acting Ethically*. Incidents in this category found participants grappling with an unexpected event that led to one of the following types of failure: (1) Personal Failure, (2) Technical Failure, or (3) Legislative Failure. Table 4 provides a summary of each theme and the participants who had an incident type grouped here. Only five participants' experiences were grouped here. Hence, these types of incidents were rare (i.e., 5 out of 81), but substantive for the participants.

Table 4. Ethical Failure Themes, Thematic Descriptions, and Participant Mapping

Theme	**Description**	**Participants**
Personal Failure	Inability to act in a way that one perceives as ethical, potentially due to factors beyond the self (e.g., when higher-ups in the company make decisions on your behalf).	Iowa, Jordan
Technical Failure	Experiencing technology functioning in an unanticipated way and which does not meet performance expectations, then striving to generate an appropriate response.	Ferrari, Walter
Legislative Failure	Inability to reach a desired end or outcome due to regulatory and legal issues arising from competing claimants and uncontrollable parameters.	Sarah

As one example of the *Personal Failure* theme, Iowa described an experience within her company wherein "we had a certain section of sewer piping, and we knew that the waste water in that piping had a pH outside of the range of what we allow." Iowa generated a solution that lined the exterior of the piping with fiberglass. She perceived this solution as ethically sound and aligned with her environmental values but also expensive. The company opted for a less expensive solution that she viewed as less preferable than her fiberglass proposal. Iowa discussed the experience in detail, including how she ultimately perceived the decision as ethical because it met expected thresholds to control potential contamination. However, the solution was misaligned with her own personal values; thus, she perceived it as a personal failure. This experience solidified her awareness of price considerations in ethical decision making and helped her draw a line between what she perceived to be moral and ethical solutions. As Iowa described:

> We ended up not doing that. Because it ended up being deemed not necessary. We had other engineers who were also utilities engineers who do sewers and things like that supporting it, some for some against. It became a discussion, and in the end, we decided not to do this lining. But for me I felt like I was really trying to fight the good fight, and better safe than sorry. […] for me that felt like not an unethical decision at all, because we had plenty of technical information to back up that everything was totally fine, but it wasn't ethically ideal. […] And I do want to reiterate, it wasn't an ethically bad decision,

> it was very technically sound, but I think for me it was a very ... It felt very personal because the reason that I was pursuing that so aggressively in the first place is that for me, environmental protection, that's a personal value. That's more of a moral thing. […] I realized that… they're usually willing to go above and beyond to make things ideal, to a point. […] There's a price for everything, and I think what was clear to me through this experience was just what that price was. They'll be supportive of something until it gets past a certain dollar mark. And then it just becomes impractical. So for me, that's kind of what I took away from it. More clarity on where that line is.

Notably, no participants in our study discussed any extreme ethical encounters or decisions that had widespread negative impacts. Perhaps this was due to the sensitive nature of failure, both proprietarily and personally. Likewise, we captured no incidents that involved substantive levels of moral courage (i.e., whistleblowing) or severe misconduct (i.e., fabrication).

Category 4: Interpersonal Encounters

This category contained incidents describing change due to interpersonal engagement with others across various contexts. Five themes defined this category: (1) Collaboration & Negotiation, (2) Convincing Others, (3) Observing Distinct Perspectives, (4) Experiencing Minoritization, and (5) Observing Questionable Behavior (see Table 5). Since most experiences related to ethics do not occur in a vacuum, many of the other incidents outside of this category had some elements of interpersonal encounters. However, in this category, the interactions were the main contributor to change. This category included 12 incidents from 11 participants.

Table 5. Interpersonal Encounters Themes, Thematic Descriptions, and Participant Mapping

Theme	**Description**	**Participants**
Collaboration & Negotiation	Engaging distinct perspectives and collaboratively working through potential disagreements to generate a response that is acceptable to all engaged parties.	Asics, Cy, Johnny, Sarah, Walter
Convincing Others	Striving to convince another person to follow appropriate or accepted ethical practices.	Raider
Observing Distinct Perspectives	Observing distinct ways of thinking about ethics and juxtaposing such perspectives with respect to one's existing view of ethics.	Angela, Rich
Experiencing Minoritization	Direct experiences of discrimination or being alone or in the minority. Incidents may either be acute or continuous.	Angela, Rachel
Observing Questionable Behavior	Observing behaviors which are ethically questionable. Actions or responses of others might provide a basis for one to reflect on the type of engineer that one aspires to be.	Charlie, Chesterton

In these incidents, engineers tended to engage individuals within their own companies, such as colleagues, superiors, or employees. In the Collaboration & Negotiation theme, the context for such interpersonal encounters often involved defining the appropriate levels of acceptability for an ill-structured problem among colleagues. When such conversations in gray areas arose, negotiation became especially important and prompted new ways for thinking about ethics. For example, Johnny described an experience negotiating an acceptable process for prototype validation:

> The development engineer wanted to use that lab as his validation lab, as his final end all, be all, hey, it does what it's supposed to do. The pushback that I had to provide was that it can't be considered a validation lab or a final validation lab because some of those processes and procedures and manufacturing will change once it gets to a point where it's ready to enter production. So, basically, we just, we found common ground.

Later in the interview, when asked to reflect on how this experience influenced his way of thinking about ethics, Johnny responded:

> I think the viewpoint that changes the most is that you hear about different situations, whether it be through schooling or through trainings, you hear about certain situations, and they all seem very black and white, very obvious, like this is what you should do, this is what you shouldn't do. When you get into the real world, there's a lot more gray area, and a lot of decisions that businesses make reside in that gray area. […] it's about discussing where those interpretations come from and where they lie, and then to have an ability to understand where the other person is coming from.

While incidents in this category are like those in Category 5 (*Mentorship and Management*), these incidents generally involved participants engaging in some form of disagreement among individuals and, thereby, considering perspectives that were incongruent with their initial perceptions. Their engagement with this dissonance led to new understandings and ways of experiencing engineering ethics for themselves.

Category 5: Mentorship and Management

This category overlapped with the *Interpersonal Encounters*, *Acting Ethically,* and *Ethical Failure* categories. Here, however, the key change involved some form of mentorship or managerial decision-making. We grouped three themes here: (1) Receiving Mentorship, (2) Providing Mentorship, and (3) Managerial Judgment Calls. Table 6 summarizes these themes and lists the eight different participants here who had a critical incident in this category.

Table 6. Mentorship and Management Themes, Thematic Descriptions, and Participant Mapping

Theme	Description	Participants
Receiving Mentorship	Receiving mentorship to work through ethical challenges. These tend to be personal and one-to-one. Incidents were often, but not always, continuous (i.e., a mentor was there when/as needed). Mentors might provide direct guidance and/or demonstrate/scaffold approaches, perspectives, and mindsets	Dick, Eric, James, Johnny
Providing Mentorship	Striving to support the individual personal and ethical growth for mentee(s).	Raider, Sarah
Managerial Judgment Calls	Making managerial judgment calls pertaining to human resources, such as deciding how to support struggling employees or deciding when and how to discipline poor performance.	Angela, Ferrari

This category overlapped with other categories, but the key dimension that differentiated this category from others was the guidance offered or provided in mentorship or managerial contexts. For example, Dick described the importance of a mentor who guided him in times of uncertainty. As part of those experiences, Dick was also given the opportunity to struggle through ethical challenges and, potentially, experience micro-failures. Dick illustrated how his mentor taught him to navigate engineering problem in a complex system:

> I struggled with some stuff and didn't really know what to do a lot of times, and probably did things wrong. But at the end of the day I'm thankful that I work for a company where I was ... And my mentor was good enough to not let a lot of that slip by. [Interviewer: I haven't really heard about the mentor before, can you talk a bit about the role the mentor played?] Well sure. I mean, he just kind of showed me what it's like to look at an engineering problem in our industry, or for our company, and to look at our procedures differently than ... Well, to look at our procedures in the context of, what is truly trying to be conveyed, what is truly trying to be solved? […] So he really taught me how to break things down, whether it be an engineering problem, or a procedural problem, or a relationship problem within the company, and to really, truly problem solve what the problem really was. Not problem solve for a solution, but problem solve for the problem. I kind of mentioned that before. The big battle I think, especially in really complex systems is, do you really have the right problem identified?

Category 6: Reflection & Associations

This category found participants connecting experiences outside of the workplace to one's way of experiencing ethics within the industrial context. This category contained three themes: (1) Societal Cases or Disasters, (2) Personal Experiences, and (3) Study Participation. Themes contained six incidents across five participants (see Table 7).

Table 7. Reflection & Associations Themes, Thematic Descriptions, and Participant Mapping

Theme	Description	Participants
Societal Cases or Disasters	Engaging or reflecting on newsworthy engineering ethics incidents. Considering how one might act if they encountered a similar situation.	Cy, Maya
Personal Experiences	Reflecting on events in personal life in order to consider novel approaches to or ways of thinking about ethics within the workplace.	Asics
Study Participation	As a part of the study, critically reflecting on myriad workforce, educational, and personal experiences. Verbalizing and seeking to rationalize one's perspectives, including how those may have changed over time. Potentially experiencing and striving to alleviate dissonance.	Asics, Eric, Rich

As an example of the themes in this category, the Societal Cases or Disasters theme found participants reflecting on newspaper-worthy ethics incidents and relating those experiences to one's practice. For example, Maya discussed the publicity associated with disasters or scandals, such as the Volkswagon airbag scandal, and states, "I think those are good reflective points for engineers to assess what ethical decisions they're making and if they are choosing the right paths in their problem solving." The Study Participation theme was intriguing, as our phenomenographic interview protocol was designed in such a way where interviewers were not imposing any specific view of ethics, but rather challenging participants to verbalize their own. Eric suggested that the interview itself forced him to critically reflect on his views of ethics, and that by the end of the interview his view was malleable:

> In thinking about this whole interview, again, I think I'm starting to realize, I think maybe my understanding of ethics is pretty narrow. I think maybe there's more broader. Whereas, I think because I work for an implant company, I think of it as barely, "What does my device do? How's it effecting patients? Is my decision ..." Whereas, there's more ethical ... things from business dealings, business practice, contracts, and IP, and all these other things.

Category 7: Prior Ethics Training

This final category involved the change induced by ethics training or preparation outside of the work context. We grouped two themes here: (1) Professional Engineering Exam and (2) Prior Ethics Coursework. We grouped four experiences by four different participants here.

Table 8. Prior Ethics Training Themes, Thematic Descriptions, and Participant Mapping

Theme	Description	Participants
Professional Engineering Exam	Preparing for, completing, and/or reflecting on Professional Engineering Exam. Note, for Carl and Iowa this was the U.S. exam, and for Walter this was the Canadian exam.	Carl, Iowa, Walter
Prior Ethics Coursework	Engaging with explicit ethics-related learning experiences during one's time as a student.	Maya

Here, the Professional Engineering Exam theme was more common than Prior Ethics Coursework. Carl discussed the importance of passing the Professional Engineering exam paired with the annual training required to hold professional engineering status. Iowa, on the other hand, noted that preparing for the exam was more critical. As Iowa stated, "In studying for my PE I realized that, as an engineer you do have public trust. And there's a lot of integrity that rests on your shoulders you need to maintain." Finally, Walter discussed the Canadian exam, which he defined as an "ethics-based exam" that involved "rather than a "technical competence exam" like the U.S. version. The fundamental distinction, according to Walter, was that the Canadian version involved making "risk-based judgments of the acceptability or suitability of something for introduction and use." To do so, technical competence is important, but not the penultimate factor.

Discussion

Findings from this CIT study relayed seven categories of critical experiences that potentially contributed to changes in ways of experiencing ethics in engineering: (1) *Cultural Immersion*, (2) *Acting Ethically*, (3) *Ethical Failures*, (4) *Interpersonal Encounters*, (5) *Mentorship and Management*, (6) *Reflection and Association*, and (7) *Prior Ethics Training*. *Cultural Immersion* was the most saturated category (34 of the 81 incidents from 18 of the 25 participants) and *Prior Ethics Training* was the least (4 of the 81 incidents from 4 of the 25 participants). This section includes two primary parts: (1) the importance of organizational cultural immersion, (2) potential implications for post-secondary engineering education.

Culture and Ethics

Most of the participants in this study (18 out of 25) described company culture as critical to their way of experiencing ethics in engineering. This finding aligns with Vaughan [12]'s ethnographic account of the importance of workplace culture in ethical practice. *Cultural Immersion* included many "continuous" events that challenged prior conceptualizations of Critical Incident Technique, i.e., viewing incidents as acute or singular experiences that lead to some sort of eureka moment (i.e., an epiphany). However, incidents in this category tended to contain myriad experiences that, when taken together, chronically became "critical". While incidents in this category were continuous or repeated over a longer term, these incidents often aligned with more acute processes like observing or collaborating with others (*Interpersonal Encounters*) and receiving direct mentorship from others (*Mentorship or Management*).

We vacillated between situating some incidents in a distinct "workplace training" theme versus the existing "workplace culture" theme. Namely, in two incidents, we finally opted to group these incidents into the latter theme and, thereby, dissolved the former. This suggests the importance of not only offering ethics training, but supporting that with myriad repeated practices throughout a company and an individual's day-to-day practice, such as messaging, reinforcement practices, etc. In other words, training exists in the larger context of the company culture, and cultural immersion precedes and/or facilitates engineers' learning of ethics.

Hence, what one deems as ethical engineering practice may be largely constructed within the organization and largely influenced by cultural norms. Davis [13] identified three types of engineering companies: engineer-oriented, customer-oriented, and finance-oriented. Arguably, these distinct company types also inculcate different norms in individual's ethical decision-making, thus suggesting the importance of a workplace culture on promoting certain types of values and ethical decision-making processes. Therefore, in line with Davis's suggestions, we would also argue ethics educators need to consider how to help students to navigate complex cultural and/or contextual issues. For example, ethics educators in engineering might consider helping students to anticipate the influence of organizational culture, such as having cultural literacy, and providing instruction concerning cultural change.

Post-Secondary Considerations

The multiplicity and diversity of the incidents we identified was notable. We identified 7 categories and 25 themes of incidents as critical to change in ways of experiencing ethical engineering practice. This might suggest a promising opportunity for new pedagogies and ethics training strategies. While most critical incidents involved some form of interaction with others in culture, the *Reflection & Associations* category found participants making sense of myriad experiences on a personal or individual level.

For example, one theme in that category found participants contextualizing societal cases and disasters to their current modus operandi. The category also involved the theme *Study Participation*. This theme was particularly intriguing, as it found participants making sense of myriad experiences based on a 90-minute individual interview. The study procedures challenged participants to critically reflect on their experiences and organize their own meaning of ethical engineering practice. This may have potentially helped to broaden their understanding of ethics in engineering. What is noteworthy here is, although the interview protocol was semi-structured, the questions were mostly centered on helping interviewees to reflect on their own experience in depth. Hence, we cautiously recommend this theme as one heuristic that instructors or leaders utilize to cultivate critical reflection among students and employees.

Finally, we identified only one (out of 81) critical experience that we related to prior ethics coursework from college. As this study synthesized interviews that focused on workplace experiences and *not* post-secondary experiences, this might partially explain this finding. However, near the end of every interview, we asked participants, "What experiences do you

believe contributed the most to your understanding of ethics in engineering?" Here, participants had the freedom to refer to the experiences they had thoroughly discussed, experiences outside of the work context in one's personal life, or any prior academic training. Although cautious, we posit that the limited references to post-secondary ethics curricular experiences might suggest a potential disconnect between ways of experiencing engineering ethics in practice and post-secondary engineering ethics education that invites further investigation. Our third phase of the research project is aimed directly at this concern.

Limitations & Future Work

First, this study presents results from a subset (25/43) of interview participants. In the future, we will incorporate all participants and identify a complete categories and themes. With that said, we anticipate that this data is near saturation, particularly at the category level (i.e., we do not expect categories to change much as we move forward).

Second, in the future work we intend to more thoroughly consider the connection between these critical incident study and the phenomenographic study [6], [7]. For example, we will likely analyze whether certain themes of change were more prominent for participants in certain phenomenographic categories of ways of experiencing ethical engineering. In addition, we will likely adopt a second and separate analytic lens, focused not only on *potential causes* of change, but also the *potential nature* of changes. As we discussed earlier in this paper, we did not anticipate the findings about change incidents and influences to necessarily be normative. Our focus has been primarily on investigating the various influences themselves, which elicit whatever changes. In the future, we will also consider the nature of changes, too.

Third, we intend to more thoroughly consider how our categories and themes are related to prominent engineering ethics frameworks and moral developmental theories. While this work has begun, we do not anticipate that we can make these detailed connections until both this CIT and phenomenographic analyses are finalized.

Finally, this study only focused on engineering practitioners in the health products industry. Limiting our scope to one industry helped contextualize our study, but we are uncertain of the transferability of these findings to other contexts at this time. In the future, we hope to explore similarities and differences in engineers from different industry sectors' learning experiences related to ethics in engineering.

Conclusion

In this paper, we applied Critical Incident Technique (CIT) to identify potential causes of changes in ways of understanding ethical engineering practice in the health products industry. We identified 81 incidents which we sorted into 25 themes and seven categories: (1) Cultural Immersion, (2) Acting Ethically, (3) Ethical Failures, (4) Interpersonal Encounters, (5) Mentorship and Management, (6) Reflection and Association, and (7) Prior Ethics Training. We

discussed the importance of culture and continuous strategies for promoting ethics in practice. In addition, we discussed post-secondary considerations, including potential critical reflection strategies coupled with personal experiences that might stimulate more comprehensive ways of experiencing ethics. The main takeaway from this study is the pervasive importance of cultural immersion on individuals' learning of ethics.

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